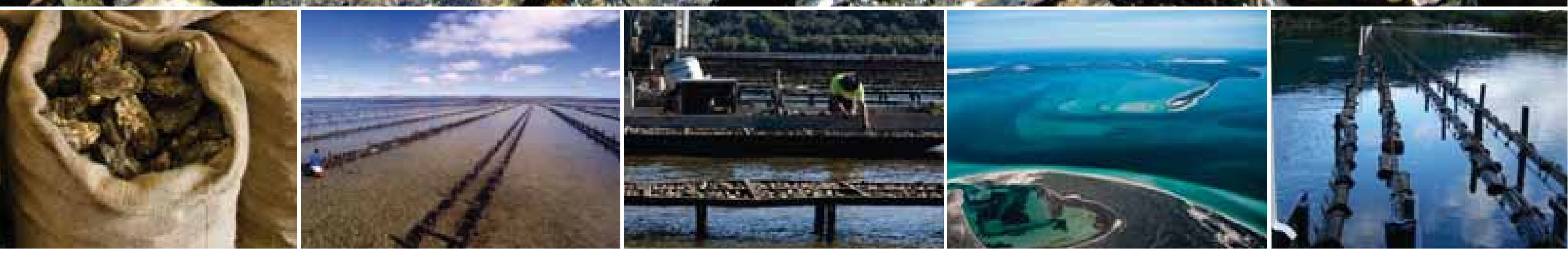
Climate Change Adaptation in the Australian Edible Oyster Industry: an analysis of policy and practice



The oyster industry occupies a unique geographical position in bays and estuaries, on the cusp of land and sea. This position makes the sector potentially vulnerable to changes in both terrestrial and oceanic environments. Projected climate changes are likely to mean that oyster growers will need to adapt in diverse ways across the many places in which they work. To encourage adaptation industry bodies and governments may also need to develop their approaches, programs, policies and practices.

This report identifies key collective actions and opportunities for adaptation for edible oyster aquaculture in Australia.

by Peat Leith and Marcus Haward

UTAS

NCCARF
National
Climate Change Adaptation
Research Facility
Adaptation Research Network
MARINE BIODIVERSITY AND RESOURCES

Climate Change Adaptation in the Australian Edible Oyster Industry: an analysis of policy and practice

Peat Leith[1,2] and Marcus Haward[1,3]

1. Adaptation Research Network Marine Biodiversity and Resources
2. School of Geography and Environmental Studies, University of Tasmania
3. School of Government, University of Tasmania

Please cite this report as:
Leith, P.B. and Haward, M. (2010) Climate Change Adaptation in the Australian Edible Oyster Industry: an analysis of policy and practice. University of Tasmania, Hobart, Tasmania.

ISBN: 978-1-86295-582-0

Acknowledgments
Many people have contributed to this report in diverse ways. Rosemary Sandford instigated the project as a key component of the initial UTAS bid for the Adaptation Research Network Marine Biodiversity and Resources and oversaw the activity in its initial stages during 2009. Anna Lyth was also instrumental in the project design. It would not have been possible to do this work without the participation of oyster growers from around the country who freely gave their time and expertise to attend workshops and review the draft report and provide comments. Staff of government agencies, research organisations and representatives of industry bodies have also provided invaluable input and, in some cases substantive contributions to the content of this report. In particular we like to acknowledge the contributions made to this report by Wayne O'Connor and Tim Gippel (Industry & Investment NSW), Luke Fraser (PIRSA Aquaculture), Xiaoxu Li (SARDI), Alastair Morton (DPIPWE, Tasmania) and Zoe Doubleday (TAFI, Tasmania). Despite their substantial contributions to it, this report does not necessarily express the views of these individuals or organisations. Thanks also to those who commented on the draft report, and especially to Ana Rubio, NRM South (Tasmania), PIRSA Aquaculture and DPIPWE Marine Farming Branch for detailed input, and to Clare Brooker for proofreading a final draft. Although all these contributions have been instrumental to the production of this report, the authors remain responsible for this analysis, the recommendations and any omissions or errors herein.

The work on which this activity is based was funded through the
National Adaptation Research Network for Marine Biodiversity and Resources.

Cover Images used with permission from Tony Troup (large front), and (left to right) I&I NSW, SAOGA, Oyster Tasmania, T. Troup, I&I NSW, SAOGA??, and SAOGA (Coffin Bay). Photographs in Executive Summary: T. Troup (pg. 1 [right] and pg.8 Box 2); Oysters Tasmania (pg. 6 [left],11,) SAOGA (pg. 2, 3 and 4), I&I NSW (pg. 8-9 spread).

Contents

Table of Figures

Table of Tables

Executive Summary

1.1
Introduction

The oyster industry occupies a unique geographical position in bays and estuaries, on the cusp of land and sea. This position makes the sector potentially vulnerable to changes in both terrestrial and oceanic environments. Projected climate changes are likely to mean that oyster growers will need to adapt in diverse ways across the many places in which they work. To encourage adaptation industry bodies and governments may also need to develop their approaches, programs, policies and practices. This report identifies key collective actions and opportunities for adaptation for edible oyster aquaculture in Australia.

The report is a review and synthesis of knowledge about climate impacts, the potential to build adaptive capacity and resilience, and to define adaptation options within the Australian edible oyster industry. We focus on the three main oyster growing states – New South Wales (NSW), South Australia (SA) and Tasmania (TAS), and detail the development and application of a rigorous social research methodology to integrate knowledge from diverse stakeholders in order to find pathways for adaptation in policy and practice. This approach, referred to as Rapid Collaborative Vulnerability Assessment (RCVA), draws together information and knowledge from various scientific disciplines and researchers, government agencies and their staff, and the local understandings and experience of oyster growers and industry representatives. The outcome is a broad-ranging and inclusive view of options and priorities for managing climate variability and change in the sector. We highlight possibilities for improving policies and practice, as well as the institutions and networks which underpin communication, knowledge production and decision-making.

Participants in this activity were generally enthusiastic about developing partnerships which will improve understanding of the drivers of change in oyster aquaculture, and in bays and estuaries, and thereby improve responsiveness to unexpected events and allow diverse adaptation options to be developed. The process for ongoing improvement of institutions, networks, programs and policy was widely considered to be fundamental to improving adaptive capacity of the sector.

Key recommendations from synthesising across workshops and the relevant scientific literature include specific cross-jurisdictional and regional priorities for building such adaptive capacity and resilience, such as:

- **Investigation and development of improvements in coastal and estuarine monitoring programs, which integrate automated and other monitoring and utilise a central repository for data;**
- **Ongoing improvement and, where possible, streamlining of processes for regulatory compliance and assessment of development and planning applications for oyster aquaculture;**
- **Continued efforts between growers, industry, banks and state government to ensure that growers are able to borrow against lease entitlements;**
- **Continued development of knowledge-action networks that include growers, industry bodies, scientists, regional Natural Resource Management (NRM) organisations, and representatives of state and local government; and**
- **Ongoing development of industry-government relations through effective communication of clear and concise information that allows reciprocal understanding of the process of oyster farming and needs of growers, on the one hand, and of government regulatory and approvals processes on the other.**

1.2
Oyster aquaculture across three states

Across the three states, two species of oysters are grown in diverse situations. In NSW the native Sydney Rock Oyster (SRO), Saccostrea glomerata, is the main product grown in estuaries, tidal lakes and lagoons. Increasingly, the NSW industry is diversifying into exotic Pacific Oysters (POs), Crassostrea gigas, which dominate the product in SA and TAS. The native flat oyster, Ostrea angasi, is grown in small quantities in all three states, but is not considered in this report. As filter feeders, oysters are susceptible to changes in water chemistry, temperature, and the availability of algae and other food. The largely estuarine-based industry in NSW and TAS is affected by upstream human action that alters environmental flows and water quality. Bacterial matter, turbidity, salinity, water temperature and a variety of other factors can make oysters vulnerable to disease or lead to loss of condition. Key features of the industry are indicated in Table 1.1. In SA, oyster aquaculture mainly occurs in oceanic bays, in which terrestrial impacts are usually negligible. The TAS and SA industries are wholly dependent on hatchery reared juvenile oysters (spat), mostly from Tasmanian hatcheries. There has been a concerted and relatively successful effort to breed SROs for resistance to their two main diseases, QX and Winter Mortality. Breeding programs gained substantial support following QX outbreaks which destroyed the industry in two of the most important estuaries in 1994 (Georges River) and 2004 (Hawkesbury River). In NSW it is not uncommon for large-scale SROs kills following heatwave conditions, especially in the north. Biotoxins from harmful algal blooms (HABs) can contaminate oysters in all areas making them harmful to humans, and in some cases lethal. Some areas are much more susceptible to HABs than others.

Table 1.1: Key issues that affect management and their overlaps across the three main oyster growing states

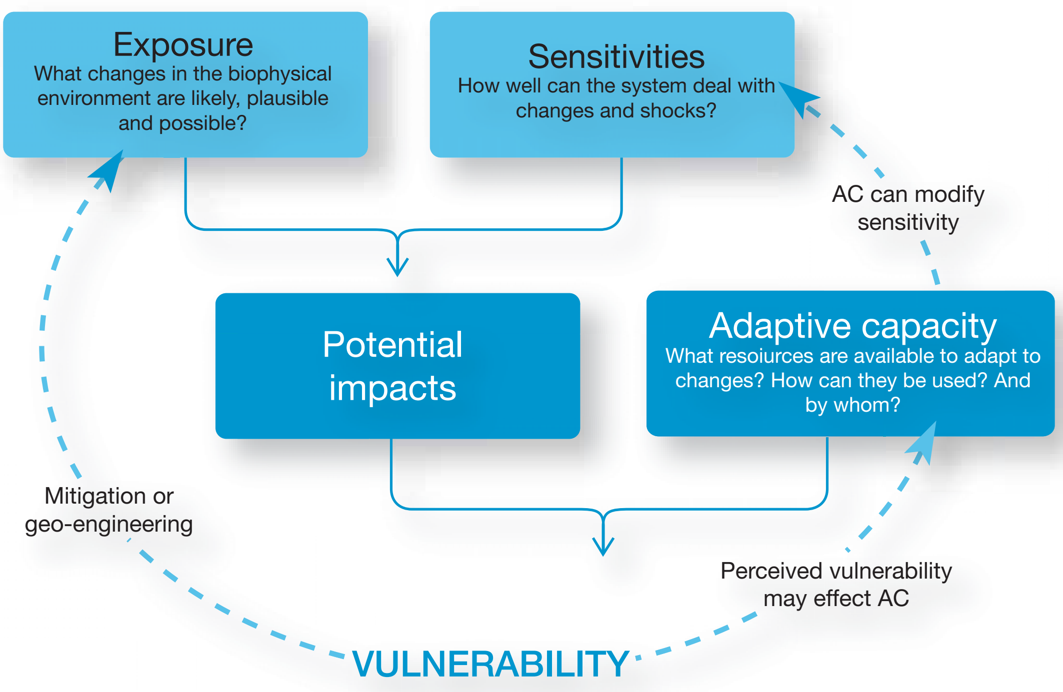
	South Australia	New South Wales	Tasmania
Main oysters Grown	Pacific Oyster	Sydney Rock Oyster, Pacific Oyster increasing	Pacific Oyster
Oyster growing environments	Oceanic Bays	Estuaries, bays and tidal lakes	Estuaries, bays, and tidal lakes
Source of spat (juvenile oysters) for industry)	Hatchery	Wild caught, with hatchery-reared increasing	Hatchery
Key diseases and causes of oyster mortality	Summer Mortality, unexplained mortality	QX more in the north, Winter Mortality in the south, overheating of beds	Unexplained mortality

Across the three states there are similarities and differences in governance - in terms of legislation, policies, institutions, and relationships among various stakeholder groups. The degrees to which industry groups are organised, coherent and well co-ordinated also varies between and within states. Relationships within industry and between industry and government are crucial to adaptive capacity because they enable collective action and generate or delimit trust. These relations are complex, multifaceted and variable across space and time. The bases of arrangements and relationships are detailed in Section 4.2, and discussed in terms of how they constrain and enable adaptive capacity in Section 5 and 6.

1.3
Approach to Rapid Collaborative Vulnerability Assessment (RCVA)

The RCVA approach applied in this report brings together scientific, local and policy knowledge across scales and jurisdictions. Including diverse forms of knowledge is necessary because thinking through adaptation requires consideration of the diverse perspectives, experience and needs of as many stakeholders as possible. Because there are substantial uncertainties about how climate changes will impact particular sectors in specific localities, adaptation will often proceed as responsive to change rather than pre-empting particular shifts. A key to enabling continuous adaptation is identification of things that constrain and enable the capacity of communities or sectors to adapt. Considering vulnerability in terms of potential impacts, adaptive capacity and the feedbacks among these and their sub-components (Figure 1.1) allows for a relatively holistic view of oyster aquaculture as a network or system with inter-connected social and ecological components.

Figure 1.1: Defining vulnerability as process, rather than outcome highlights the potential feedbacks in social-ecological systems (adapted from Allen Consulting (2005)



The process of integrating knowledge about the social-ecological system of oyster aquaculture was done in four stages (see Figure 1.2).

1. First, it moved quickly from a preliminary desktop investigation of the policy, science and practice of oyster aquaculture across NSW, SA and TAS, to engaging staff of relevant government agencies across the three states in a series of workshop to discuss state-wide policy drivers of adaptation and adaptive capacity. These workshops ensured the process could address relevant and legitimate questions for these government agencies.

2. The initial workshops helped to orient the subsequent stage of the process: a synthesis of scientific literature about potential impacts of climate change and sensitivities of oysters and of oyster aquaculture at the scales of organism, farm and industry.

3. The third stage of the process was a series of regional workshops with oyster growers, industry representatives, and various stakeholders from local and state government, regional NRM bodies, scientists and other interested parties. Five workshops across the three states with 56 participants highlighted key issues and priorities for the development of adaptive capacity for the industry and an understanding of regional vulnerabilities through discussion of the scientific, practical, economic and governance issues that affect the sustainability of the sector.

4. All the above work was pulled together and analysed and reviewed by the project team and an extended peer community of growers, and industry and government participants.

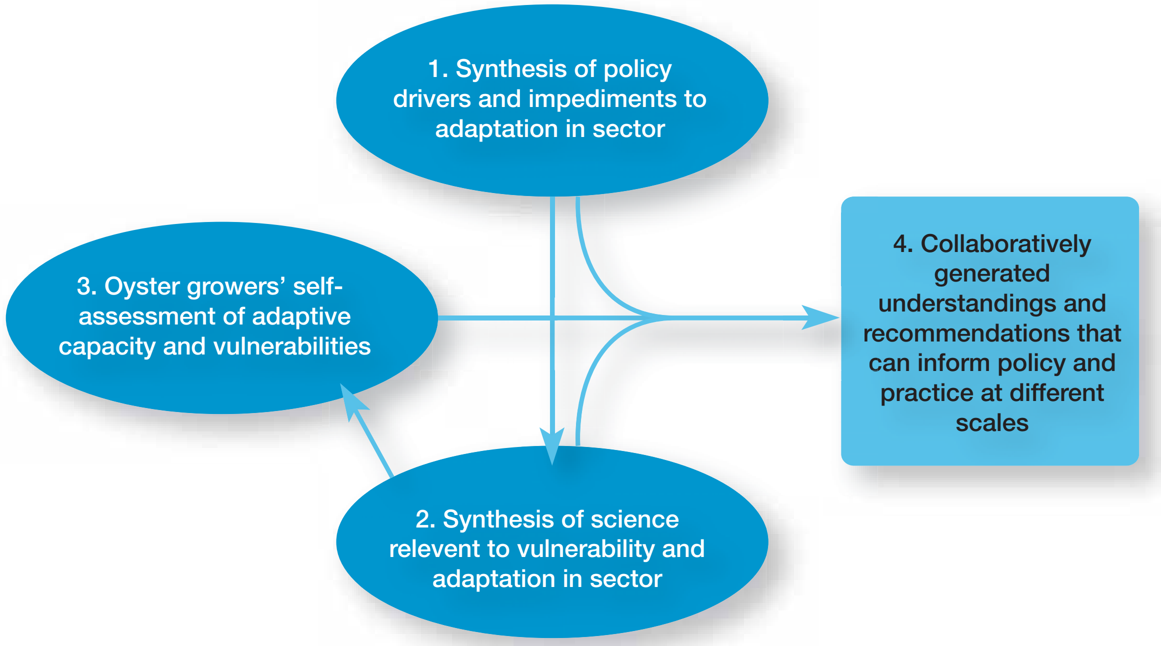


Figure 1.2: Schematic of approach to stages of RCVA applied in this project.

Five regional workshops were conducted in NSW (Batemans Bay and Forster), SA (Streaky Bay and Port Lincoln) and TAS (Campbell Town). The workshops were attended by a total of 56 participants, including 33 oyster growers, and facilitated to identify and discuss issues of concern and prioritise collective actions to build adaptive capacity. Adaptive capacity was self-assessed by workshop participants through a discussion which identified key indicators that underpin regional capacity to adapt using a livelihoods framework (see Box 1).

Capital	Summary of capital
Human	the skills, health (including mental) and education of individuals that contribute to the productivity of labour and capacity to manage land.
Social	the social bonds that facilitate cooperative action and the social bridging, and linking via which ideas and resources are accessed.
Natural	the productivity of land, and actions to sustain productivity, as well as the water and biological resources from which rural livelihoods are derived.
Physical	built capital items produced by economic activity from other types of capital that can include infrastructure, equipment and genetic resources.
Financial	the level, variability and diversity of income sources, and access to other financial resources (credit and savings) that together contribute to wealth.

Box 1: What is adaptive capacity?

Adaptive capacity can be thought of as the resources available to adapt to change as it occurs, and the capability to deploy these resources in order to achieve adaptation goals. A livelihoods framework was used in the workshops to categorise indicators of adaptive capacity into five types of capital – human, social, physical, natural and financial.

Up to five indicators were derived for each of the capitals and subsequently rated according to how constraining or enabling each indicator was perceived to be, and the degree to which the indicator could be changed. Collective actions needed to develop adaptive capacity were discussed in relation to the indicators derived for each capital (see Section 3).

1.4
What potential impacts will climate change have on the edible oyster industry?

Changes in ocean currents and climate variables already affect oyster aquaculture substantially from year to year and season to season. In many cases these effects are likely to become more pronounced under future climate change scenarios. Specific impacts in each state are associated with particular changes include:

Strengthening East Australian Current: May lead to warmer temperatures and lower nutrient status in estuaries and lakes of NSW and TAS, and is likely to change the timing of oyster growth and spawning. Changing water temperatures and windows for algal blooms are likely to alter the frequency and types of algal blooms that occur in a particular area, and may result in the emergence of unprecedented HABs. Changing water temperatures may also affect the distribution and intensity of disease outbreaks in SROs.

Rainfall changes: In NSW and TAS, projected changes in rainfall patterns may affect the period of time that estuaries are closed for harvesting. An important projection for oyster aquaculture is that rainfall is likely to become more sporadic, with heavy rainfall events followed by longer periods of dry weather and increasing evapotranspiration. Along with increasing human demands on water supplies and changes in land use, these issues could exacerbate bacterial contamination and turbidity in wet periods and reduce nutrient availability in dry periods. Changes in salinity in lakes and estuaries are also plausible, which can affect susceptibility of SROs to diseases. Low salinity can also stall growth and sometimes result in mortality of POs.

Increasing frequency of heatwaves: The projected increase in air temperature could lead to more summer kills of Sydney rock oysters, especially in northern NSW, and may also result in higher incidence of Summer Mortality in SA. These effects could be exacerbated by higher sea-surface temperatures.

Sea-level rise: Projected sea-level increase of up to, and possibly exceeding, 0.8 metres over the 21st Century will affect land-bases of oyster farming operations in NSW and TAS. Storm surge activity may exacerbate these impacts, and might make changes in exposure to wind and wave conditions greater in some areas. Modifications and upgrades of lease infrastructure are likely to be a necessary part of ongoing adaptation.

Acidification: Gradual increases in acidity of oceans will affect oyster reproduction and ability to lay down shell. Juvenile oysters (especially larvae and spat) will be most substantially affected. Some breeding lines and species appear more susceptible to acidification than others and this is a field of current research.

Climate change will affect oyster aquaculture in differing ways in different places. Although some changes, such as acidification, are likely to be gradual and incremental, most of the impacts will be felt as increased frequency or intensity of extreme events, such as floods, droughts, heatwaves and storm surges. Therefore increasing capacity to manage for climate variability and extremes is fundamental to adapting to climate change. In NSW and TAS, climate change impacts on oyster aquaculture will often relate closely with upstream management of resources and development, and thus need to be considered in a broader societal context of NRM and landscape scale planning decisions. Adaptation is likely to require management of non-climate stressors to estuary health in order to make estuarine systems more resilient to changing conditions. Efforts to these ends are also likely to provide increased resilience of riparian and aquatic systems and of fish species that use estuaries as spawning or breeding grounds.

Box 2: A social license to operate in oyster aquaculture?

Across the workshops, oyster growers expressed the need to improve the perception of the oyster industry through better marketing and community engagement. In a nutshell, the argument here is that, in order to prosper and adapt to new situations, oyster aquaculture needs to be recognised widely as an appropriate use of public waterways, having both community and government support. This support relies on development and maintenance good relationships with the broader community.

The oyster industry generates profit, in part, from the maintenance of good water quality in estuaries and bays. Yet the degree to which the general public understand the work done by the oyster industry to ensure this water quality (and other public goods) is maintained is probably limited.

The public standing of the oyster industry is only one aspect of a social licence to operate; another form of a social license to operate comes via prioritisation of the oyster aquaculture as a social and economic outcome. In NSW the Oyster Industry Sustainable Aquaculture Strategy (OISAS) (NSW Department of Primary Industries, 2006) provides a policy basis for a legitimate social license to operate by highlighting whole-of government responsibility to ensure oyster farming is treated as a 'priority outcome' in specific areas. OISAS covers sets out how the roles and responsibilities of different agencies to ensure this 'outcome'; including how oyster aquaculture is considered in the planning process for upstream development, as well as practice guidelines and obligations for the industry and individual growers.

1.5 What constrains and enables adaptive capacity in the oyster industry?

Across the workshops, similar priorities and concerns were apparent among participating oyster growers. Indicators of adaptive capacity were also similar across the five capitals (Table 1.2). The most pervasive issues were also often rated as most substantially constraining adaptive capacity. Issues related to human and social capital included limitations in: proactive engagement within some parts of the industry culture (human capital), issues related to attracting, maintaining and developing skilled and unskilled staff (human-social), relationships between industry/growers and government agencies (social), efficiency and co-ordination in public sector management (social), issues constraining whole of catchment management (social – natural).

Physical capital issues were generally less concerning. Natural capital indicators generally related to water quality and ability to access suitable water and land resources. Key financial issues related to profitability and ability to borrow against lease entitlements. These issues are detailed in a series of tables in Section 5 of this report.

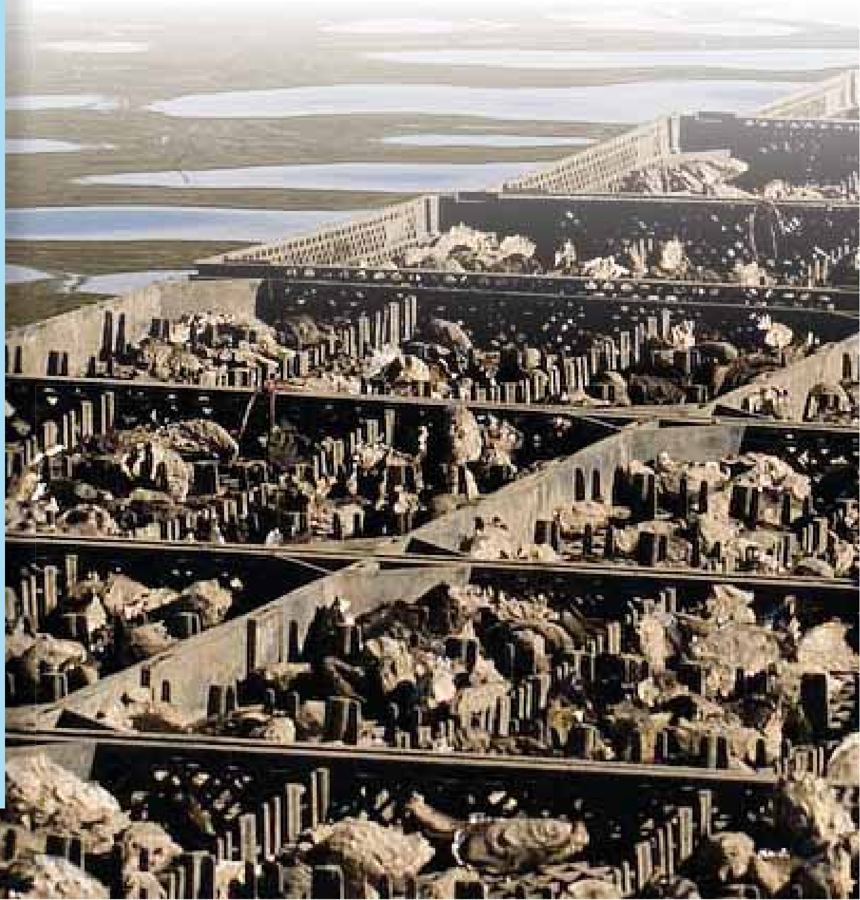


Table 1.2: Aggregated indicators of adaptive capacity across the workshops. The '+' in a given column indicates that this indicator was selected as an issue for this workshop. The colour indicates whether the indicator, on average, was considered to be constraining (dark blue), neutral (blue) or enabling (green) adaptive capacity. Relatively low attendance of oyster growers in SA workshops meant that the indicators were not rated on this scale. For more detail see the workshop reports in Section 5.4.

	Synthesised indicators	Batemans Bay (n=21)	Forster (n=10)	Port Lincoln / Streaky Bay* (n= 11)	Campbell Town (n= 11)
Human capital	Culture of apathy or conservatism among growers	+	+	+	
	Availability of unskilled labour			+	
	Availability of skilled labour	+		+	+
	Capacity for training staff		+		+
	Support for leadership	+			
	Ability to develop business (succession and expansion)			+	+
	Local knowledge and experience		+		+
	Time constraints on growers	+	+		
Social capital	Industry organisation, representation and communication	+		+	+
	Relationship with other industry bodies			+	
	Communication among growers		+		
	Industry-community interactions and relations	+	+	+	
	Information collection and collation				+
	Government - Industry relationships	+	+	+	+
	Co-ordination of management		+		+
	grower engagement with governance	+			
	Efficiency of state and local government processes				+
Natural capital	Access to productive water	+		+	+
	Inundation of landbases	+			
	Productivity of water	+	+	+	+
	Estuarine health	+	+		+
	Water safety (biotoxins and contaminants)		+		
	Heatwave frequency		+		
Physical capital	Stock genetics and breeding	+		+	
	Availability of stock	+			+
	Ability to relocate stock		+		
	Suitability of lease infrastructure		+	+	+
	Suitability of handling systems			+	
	Access to suitable landbases and foreshore	+		+	+
	Ability to change product or diversify		+		
Financial capital	Profitability of enterprises and industry	+	+	+	
	Ability to borrow against lease entitlements	+	+	+	+
	Fairness in rewards across supply chain	+			
	High overheads and infrastructure costs		+		+
	Location costs (foreshore land and living expenses)			+	+
	Cost of cost recovery programs			+	+
	Compliance costs, fees and charges			+	
	Costs associated with harvest closure				+

1.6
Recommendations: decreasing sensitivity, building adaptive capacity

The approach applied in this report generated and informed discussion about how to manage for potential climate impacts. It also focussed on steps that are necessary to make the sector more adaptive and responsive to change. In the face of uncertainty about long term climate impacts and the likelihood that many of the most substantial impacts will be related to extreme events and their aftermath, strategies that build adaptive capacity and resilience are likely to be of most general benefit. Recent local annihilation of oyster aquaculture following QX disease outbreaks indicates that the sector, especially in NSW, is not immune to dramatic changes in system function. Discussions around collective actions indicate pervasive interest and enthusiasm among participants to enter into partnerships at different scales to increase their knowledge about the biophysical systems on which they depend through monitoring and analysis of data.

Many measures for adaptation will require collaboration across traditional boundaries between industry and government. We argue that the oyster industry is uniquely positioned to take advantage of many of the imperatives of adapting to climate change, and it has substantial opportunities to partner with diverse local and regional groups to ensure that estuarine health is maintained in the face of potential changes to the ecological function of these systems. A great deal of adaptive capacity can be generated through such linkages in ways that are often difficult to predict, yet these partnerships will require commitment and rigorous institutional design to ensure they are effective and durable in the medium and longer term.

In summary, the key cross-jurisdictional recommendations are:

- **Investigation and development of a program of coastal and estuarine monitoring in which oyster growers, regional universities and regional NRM authorities are partners;**
- **Ongoing improvement and, where possible, streamlining of processes for regulatory compliance and assessment of development;**
- **Continued efforts between growers, industry, banks and state government to ensure that growers are more able to borrow against lease entitlements;**
- **Continued development of knowledge-action networks that include growers, industry bodies, scientists, regional NRM agencies, and representatives of state and local government. These networks are vital to the sustainability, adaptive capacity and growth of the industry both within and between states. They rely on clear lines of communication and ongoing relationships between individuals and organisations in which mutual respect engenders trust; and**
- **Development of industry-government relations through provision of clear and concise information that allows reciprocal understanding of the process of oyster farming and needs of growers, on the one hand, and of government regulatory and approvals processes on the other. Training and induction programs for government and industry managers could be a fruitful means of ensuring clear lines of communication and for managing expectation across boundaries.**

Recommendations that apply to specific regions, state, and across jurisdictions are detailed at the end of this report in Section 7.

Box 3: Managing oyster kills and disease in a changing climate: Genetics, Management and Environment

Large scale oyster kills have had substantial impacts on individual growers and the oyster industry as a whole. Increasingly most oyster diseases are seen as resulting from complex relationships between susceptibility of oysters, the disease pathogen(s) and the environmental conditions. Thus managing for disease outbreaks is a key aspect of climate adaptation.

Ways of avoiding disease outbreaks are generally limited by our knowledge of all three aspects of disease. But there now widespread recognition that a single fix or a silver bullet will not be address such complexity. Super oysters are not in the pipeline, and water qualities will always vary.

Oyster growers, industry bodies, governments (commonwealth, state, local and regional NRM groups) and scientists all have a part to play in addressing the various elements of disease. Genetics of oysters can be advanced through scientific breading programs. Management practices can be improved through knowledge-sharing within the industry and with researchers and through innovation. Environmental conditions can be improved through such endeavours as whole of catchment management, underpinned by ongoing improvement in monitoring and analyses.

2 Introduction

Oysters transcend their simple, resale and social values. A productive and healthy oyster industry reflects our ability to sustain and maintain healthy coastal waterways (White, 2001, pg. 14).

Oyster aquaculture serves diverse functions – ecologically, economically, socially and culturally. This report details how some of these functions of oyster aquaculture may change in the context of changing climatic conditions, and what forms of adaptation are likely to be required in order to sustain a vibrant oyster industry across the three main oyster producing states – New South Wales (hereafter, NSW), South Australia (SA) and Tasmania (TAS). The approach to thinking through climate adaptation in the oyster industry takes a broad view of the sector as a social-ecological system (SES). As detailed in Section 3, taking this approach means that diverse biophysical, social, economic and institutional aspects of oyster aquaculture need to be considered together in order to identify the key issues that constrain and enable adaptation, and to understand how these interact.

Oysters have been described as both engineers of coastal ecosystems (Ruesnik et al, 2005) and as indicators of ecological stress (New South Wales Department of Primary Industry, 2006). During their life an average oyster will filter an estimated 0.5 to 1ML of estuarine water (White, 2001) and this capacity for filtration also allows them to transfer energy and nutrients from pelagic into benthic systems as well as cycling nutrients within the pelagic system. Ruesnik et al (2005) suggest that dramatic reductions in oyster populations in some systems have resulted in those system shifting from predominantly pelagic to benthic. Conversely, when oysters are introduced into areas where they formerly did not play a significant role, they can shift the productivity of the system in the opposite direction. Thus, oyster aquaculture, in specific contexts, can influence ecosystem function or status, potentially modulating resilience of an ecosystem more broadly. Because of their sensitivity to ecological health of a system oysters are often described as the canaries of estuaries (White, 2001). Oyster production can thus be seen as presenting a private gain from what would otherwise be a public good – health of estuarine and marine coastal ecosystems. To some degree, stable oyster production reflects relative stability in water quality, although this relationship is far from a simple linear one. Management can affect the resilience of oysters to disease vectors, as can the genetics of oyster stock (Rubio, 2008).

Unlike many other forms of aquaculture, oyster farming has minimal inputs from external sources. Oysters utilise available plankton and other suspended matter (seston) for nutrition. This makes them susceptible to contamination from biotoxins present in HABs or bacterial infection from human sources. If undetected in oysters, these can cause illness or death in consumers. Although these risks are variously managed by industry and Australian State and Commonwealth Government agencies, a single illness or death has the potential to affect oyster markets across spatial scales. This implies that what happens in a single estuary or a single farm has the potential to impact the industry as a whole. These and other mechanisms interlink and distinguish oyster aquaculture across areas and states. More detailed discussion of the function of oyster aquaculture is provided in Section 4 in relation to biophysical aspects of the sector and to climate impacts. Section 4.2 outlines current governance arrangements, while Section 5 details results the perspectives of industry and growers in terms of adaptive capacity and resilience from the workshops.

The exact impacts of climate change cannot be predicted with great accuracy, especially at a local level. This is, however, the scale at which people make most of the decisions that affect their lives and livelihoods, and where impacts are likely to be most felt. Nevertheless, indications of changes already occurring along with projections from the best scientific modelling can be helpful guides that can be used by individuals and groups to help them think about what the future might hold and how to prepare for it. Such a process might not pin down a single strategy as *the* way forward; it is more likely to guide the development of contingencies – a diverse array of options that make people more able to respond to changes as they occur. This ability to respond effectively to change, to weather shocks, or to recover from substantial shifts in system function is often referred to as resilience or adaptive capacity.

Adaptive capacity can be defined as the pre-conditions required for adaptation, and the ability to mobilise these diverse elements towards adaptation (Nelson et al, 2007). These pre-conditions can be usefully conceptualised in terms of a livelihoods framework (Ellis, 2000) in which diverse assets, held within a system (e.g. a community, ecosystem, business, etc.) can be deployed to enable adaptation. Considering these assets in terms of different forms of capital makes it easier to visualise trade-offs and feedbacks occurring across different capital classes. It also provides a intuitive framework with which people can easily engage in a workshop setting (Brown et al, 2010).

This report analyses outputs of a series of workshops, and synthesises scientific information in order to advance understanding of resilience and adaptive capacity. We focus on the structural and institutional constraints and enablers of adaptation. In addition we note and explore developments within the industry (such as oyster genetics and breeding programs and improved knowledge about system function) as well as the opportunities provided through ongoing collaboration across boundaries between science, industry and government.

3 Rapid Collaborative Vulnerability Assessment (RCVA)

The RCVA approach developed for this project builds on the work of Nelson et al. (2009) and Brown et al., (2010), and enables the inclusion of diverse stakeholders in a process of collaborative assessment of vulnerability. As detailed below, the approach is not designed solely to achieve analytical outcomes (i.e. this report). We hold that an important outcome of such research ought to be the facilitation of social learning across the spectrum of participants as well as within our research network.

3.1 Linking social-ecological systems for institutional analysis of vulnerability

The growing recognition that human and ecological systems are inseparably bound has fomented a variety of approaches to analysis of governance and institutions. Scholars such as Ostrom (2007; 2009) and Pahl-Wostl (2009) insist that inclusion of key social, economic and environmental variables in analysis is essential to comprehension of interactions and feedbacks that create and delimit system function. Systems research over recent decades has repeatedly found that the dynamism of systems is a function of the interaction of human action and variable ecological conditions. Thus, intervention, whether through research, engagement, regulation, or any other instrument, can change the function of social-ecological systems in ways that can only be fully known through the experiment of management. Institutions (the formal and informal rules and relations by which behaviour is governed) come to be seen as experiments.

In western democracies resource governance is increasingly viewed as necessarily distributed across spatial scales. Interests are diverse and varied. Following widespread failure of top-down approaches to sustainably manage natural resources such as topsoil, ground breaking insights about how successful Community Based Natural Resource Management (CBNRM) can be (e.g. Ostrom, 1990; Gunderson et al, 1995; Berkes and Folke, 1998)have (with varying success) sought to develop models which are typically a mix of top-down and bottom –up: they are regionalised, poly-centric and networked systems of knowledge-making and decision-making to manage such complexity (e.g. Innes and Booher, 2003). These models have broadly fit with a tendency of neo-liberal governments to emphasise that individuals and communities must take increasing responsibility for the risks posed by the natural hazards, including those associated with climate variability and change (Dean, 1999; Lockwood et al, 2009).

Distributing power to make decisions about natural resource management implies a concurrent redistribution of knowledge. This moves beyond the perspective that people who manage resources at local and regional scales need to be provided with knowledge, ready-made by scientific researchers or organisations. Rather, knowledge production itself is increasingly viewed as most effective when it is distributed across a wide network of lay people and scientists. This perspective is summed up most succinctly by ideal of 'social learning' (e.g. Ison, 2002). Reductionist approaches to knowledge production are increasingly seen as failing to address the interactions and feedbacks which typify the function of complex socio-natural systems. Attempts to understand such system dynamics instead rely on 'post-normal science' in which knowledge-making relies on more democratic processes of inclusion than are normally associated with scientific research, and an 'extended peer community' is created (Funtowicz and Ravetz, 1993; Bray and von Storch, 1999). By these means knowledge is not just created as a credible product of enquiry, but is made relevant (in that it is applicable to real-world problems) and legitimate (in that various stakeholders understand and respect the process by which conclusions were reached) (Cash et al, 2003). These well-founded assumptions propelled the design of the process of engagement that this report details.

Vulnerability to climate change is typified by interactions between social and ecological systems. Climate vulnerability is often defined as a function of exposure and sensitivity to changes in particular meteorological variables (over differing timescales) and the ability of the broader system to adapt to such change (Figure 1.1). This definition is often referred to as the Allen Consulting (2005) Model of vulnerability. The simplicity of this schematic belies the complexity of vulnerability as it occurs in real-world situations. For instance, a classic element of sensitivity is the degree to which resource users are depend on the stable availability of particular stocks of natural resources. If analysts consider that such resource-dependency (thus sensitivity) is high in a particular community, they may conclude that this community is vulnerable. Such was the case when a drought associated with the 1997-8 El Niño resulted in crop failure in remote, subsistence communities in the highlands of Papua New Guinea. When an Australian mission arrived with food aid they found villages empty. The villagers had broken into small bands and 'disappeared' into the forest to pursue an alternate livelihood strategy – that of hunter gatherers (Allen, 2000).

Comparably, where the sensitivity of some South Pacific islands to rising sea-levels has been depicted as threatening their very existence, investment in these economies has slowed, limiting their capacity for autonomous adaptation (Barnett and Adger, 2003). Finally, at a global scale, perception or experience of climate impacts and a growing awareness of vulnerability has the potential to both hasten effective action towards emissions reduction. Yet, this concern, coupled with pessimism about the political possibility of mitigation, has also led to a recent revival of the scientistic visions of controlling climate (e.g. Kwa, 2001) via geo-engineering. These and numerous other examples starkly demonstrate that potentially powerful feedbacks exist between sensitivity and adaptive capacity, on the one hand, and vulnerability and exposure, on the other.

These feedbacks operate across temporal and spatial scales and create indeterminacy for prediction of future conditions for each of the elements of vulnerability (Shackley and Wynne, 1996). Such interactions also emphasise that intervention in systems can have unforeseen consequences upon the function of that system. The feedbacks depicted in Figure 1.1, are thus important considerations for defining vulnerability. They emphasise vulnerability as an ongoing process, rather than the sum of particular effects.

3.2 Methodology and Framework for Rapid Collaborative Vulnerability Assessment (RCVA)

The RCVA approach uses participatory processes, a synthesis of available scientific research, and a livelihoods framework in order to rapidly undertake a first pass assessment of vulnerability within a particular sector or community. Following from the considerations outlined above, we were interested in vulnerability as more than the sum of its parts; we wanted to also understand the potential interactions among these parts. The overall process of the project is summarised in Figure 1.2. Synthesis of existing scientific work relating to climate change exposure and sensitivity informed a series of workshops held across NSW, SA and TAS. The first three 'policy workshops' were held in November, 2009 and January, 2010. These involved researchers and staff of government agencies engaged in decision-making and management of oyster aquaculture. The second round of workshops, the 'regional workshops', included different stakeholders involved in oyster aquaculture, predominantly oyster growers but also staff from state and local government agencies and regional NRM organisations, scientists, oyster industry representatives and others. To clarify the process it is worth unpacking its various stages outlined in Figure 1.2.

Prior to the policy workshops, a preliminary desktop investigation was conducted and key informant discussions carried out. This provided the research team with a reasonable grounding in contemporary issues in oyster aquaculture and relevant research on climate impacts and sensitivities on oyster aquaculture. A presentation on potential impacts and sensitivities was used to focus discussion within the state-based policy workshops. The workshops were loosely organised around a series of questions which reflect the general approach to vulnerability assessment:

1. What are plausible/likely impacts of climate change on the NSW oyster industry (in terms of exposure and sensitivity)?
   1a. Which are priorities for research / action?

2. What currently enables and constrains adaptation in the edible oyster industry (in relation to human/social/natural/financial/ physical capitals)?
3. How do current policy instruments enable and constrain adaptive capacity?
4. How can this project help to inform policy for adaptation in the oyster industry?

The policy workshops were held in the offices of state agencies with primary carriage of legislation to manage oyster aquaculture in Adelaide (PIRSA Aquaculture), Port Stephens (Industry and Investment NSW) and Hobart (DPIPWE Marine Farming Branch). Following each workshop, confidential draft reports from each workshop were sent to participants to ensure their perspectives had been properly understood and recorded, and these were reviewed and amended following additional commentary and input from participants. The policy workshop resolved ways that the project could usefully inform review and development of policy across the states. It also provided helpful suggestions for ways to progress the scientific synthesis work as well as the conduct of regional workshops (see Appendix 1). The design of regional workshop was redrawn to include a session in which growers described any environmental change they had noticed locally or regionally, and another session in which growers' research priorities were discussed.

Following the policy workshops, the desktop analysis and key informant discussions recommenced, now including a variety of oyster growers and industry representatives. Potential impacts were examined across a range of timescales, and an emphasis on dealing with climate variability and extremes became a greater point of focus in thinking through impacts and adaptive capacity. Potential impacts were examined in terms of their various positive or negative connotations for regional oyster aquaculture. The presentation of impacts and sensitivities was developed such that it could help growers envisaging scenarios and think through how these might be dealt with. Workshop discussions were designed to ground these impacts in relation to growers' experience and practice and to clarify what regional scenarios might mean in the context local oyster aquaculture as well as in relation to broader regional and national concerns, such as markets, branding and co-operation or competition among regional and state industry bodies.

The central focus of the RCVA regional workshops was to develop a clear understanding of adaptive capacity and resilience and how these are constrained and enabled across oyster growing areas. This reflects the notion that adaptive capacity is the primary mode by which impacts are modulated and thereby a fundamental concern for intervention in relation to delimiting vulnerability. It also reflects a concern raised by several key informants that 'vulnerability', as a term, lacks optimism and implies helplessness, while 'adaptive capacity' and 'resilience' imply proactive engagement. The latter terms might be viewed as successful boundary objects (Star and Griesemer, 1989) – points around which different groups and individuals can find common ground and common meaning. They infer multiple possibilities rather than a single destiny (cf. Gunderson and Holling, 2001).

From a livelihoods perspective, adaptive capacity suggests a focus on the resources available and the ability to use them to adapt to change over an extended time period (Thomson and Pepperdine, 2004). This definition implies that adaptive capacity, like vulnerability, is as much about processes and relationships as it is an attribute of a person, community, industry or any other system. Capacity might thus be considered as an emergent phenomenon that enables a system change in order to deal with new perturbations and situations (Adger, 2003). Resilience, as it was first employed by Holling (1973), refers to the degree to which a system is buffered from shock, coupled with the ability of that system to maintain its critical function following a change to a different state. Thus, both adaptive capacity and resilience are a function of attributes and relations within a system. The former enables change in the face of new situations, the latter allows a system to be buffered from change or recover following it. Both terms are useful. For any given complex system, both are difficult to describe; and there is no settled method for their evaluation (Nelson et al, 2009). However, there is an emerging tradition that insists that ongoing, interactive, inductive and deductive research which integrates the social and ecological can build broader understanding of system function, including adaptive and resilience, as well as help to clarify appropriate institutional forms and interventions (Ostrom, 2007; 2009).

3.2.1 Collaborative assessment of adaptive capacity using the sustainable livelihoods framework

A sustainable livelihoods approach was adopted for this research because it offers an inductive and intuitively accessible approach to including diverse drivers of adaptive capacity and resilience in a way that is rapid, repeatable, efficient, inclusive and effective (following Scoones, 1998; Ellis, 2000; and Nelson et al., 2009; Brown et al., 2010). Using this framework, participants in regional workshops engaged in qualitative discussion about how different aspects each of five forms of capital (human, social, natural, physical, and financial – see Box 1, in the executive summary) affect their capacity to adapt to climate change. Facilitation of the discussion sought to crystallise often broad ranging dialogue and narrative, through identification of indicators of key each capital. Yet the discussion itself also clarified widely held perceptions of system function, description of important trade-offs and feedbacks across different asset classes, as well as allowing for a rapid appraisal of key points of tension or argument across boundaries.

The livelihoods framework, used in the context of a participatory workshop, provides a simple means of categorising the diverse issues that are fundamental to capacity. The facilitation of discussion around each capital was targeted to highlight central issues relating to capacity for each asset class. Yet it was also made clear that there will inevitably be overlaps between individual issues and across the capitals. Thus, for example, discussion of capacity started with human capital – the traits of individuals – and these were often described in terms of skill shortages or availability of labour, which was linked to broader macroeconomic drivers and policy issues. In this way an indicator of one capital can be identified as a key issue that might constrain capacity, yet the qualitative descriptions and narratives point to diverse cross-scale factors associated with this issue. Thinking through collective actions that might be necessary to ameliorate a particular constraint (or to strengthen enabling ones) is particularly useful for identifying perceptions of how issues are interlinked, how power is distributed, and what assumptions govern current practices of management and decision-making.

The facilitated dialogue established key indicators of adaptive capacity in relation to each capital and developed a rationale for each indicator. Dialogue often led groups to reconsider or refine an indicator that may have been initially well supported. It often highlighted other key indicators of the same capital, or a different one. Such dialogue is crucial to developing an understanding of the context of adaptive capacity within communities as it highlights points of consensus and tension within and among communities. For example, stories were often presented to make specific points and these provided a historical backdrop to adaptation, to the success or failure of collaboration, to the trends in workforce and population, to the perceived status of the social and the ecological. Where prior discussion of observed system changes or research priorities aligned with an adaptive capacity issue, we asked participants to consider what forms of collective action could deliver a change in arrangements that enabled, or at least reduced constraints on capacity.

Following workshop discussions of capacity, the newly-defined indicators for each capital were rated on two dimensions. Using radio frequency audience response keypads in conjunction with TurningPoint™ software, each participant rated each indicator on two dimensions: firstly, in terms of the degree to which the indicator currently constrained or enabled the ability of the growers in the region to adapt to changing climatic conditions, and; secondly, in terms of how resistant to change the indicator was perceived to be. For example, a common indicator of human capital relates to the skills of the broader population of oyster farmers. Skills might be viewed as insufficient to enable adaptation, and therefore constraining adaptive capacity. Yet improving skill levels at an industry level might be seen as relatively easy to do through, for example, industry/government partnerships to develop field days and promote best practice techniques. Thus indicators were rated on two 7-point scales (Table 3.1) to allow for comparison of indicators within a consistent conceptual model for thinking through prioritisation of actions to build adaptive capacity (Figure 3.1). In this model, the sector of the matrix in which an indicator is perceived to reside suggests questions about the forms of collective action required, if any. Indicators that are considered 'stable constraints, for example, may be unchangeable and thus managed as inherent system constraints (e.g.

high seasonal variability in rainfall) or require structural or institutional change before they can become enabling (e.g. lack of coordination between government agencies). Conversely, indicators that are considered as 'unstable enablers' can be evaluated in terms of whether or how they can be made more stable. Drawing on Social-Ecological Systems thinking (e.g. Gunderson and Holling, 2001) indicators that are considered to be very stable may be slow variables indicative of longer term shifts in system function, while the less stable indicators might be considered as fast variables in that they may change relatively quickly but may not be an effective measure of system function when viewed over the long term. These suppositions can be tested by the application of this model. Rating of indicators was not done in the SA workshops due to the low number of participants and their time constraints.

Table 3.1: The rating scale for the two dimensions of adaptive capacity used in the workshops across two dimensions.

1	2	3	4	5	6	7
Strongly Constraining	Constraining	Weakly Constraining	Neither constraining or enabling	Weakly enabling	Enabling	Strongly Enabling
1	**2**	**3**	**4**	**5**	**6**	**7**
Very unstable	unstable	Slightly unstable	Neither stable or unstable	Slightly stable	stable	Very stable

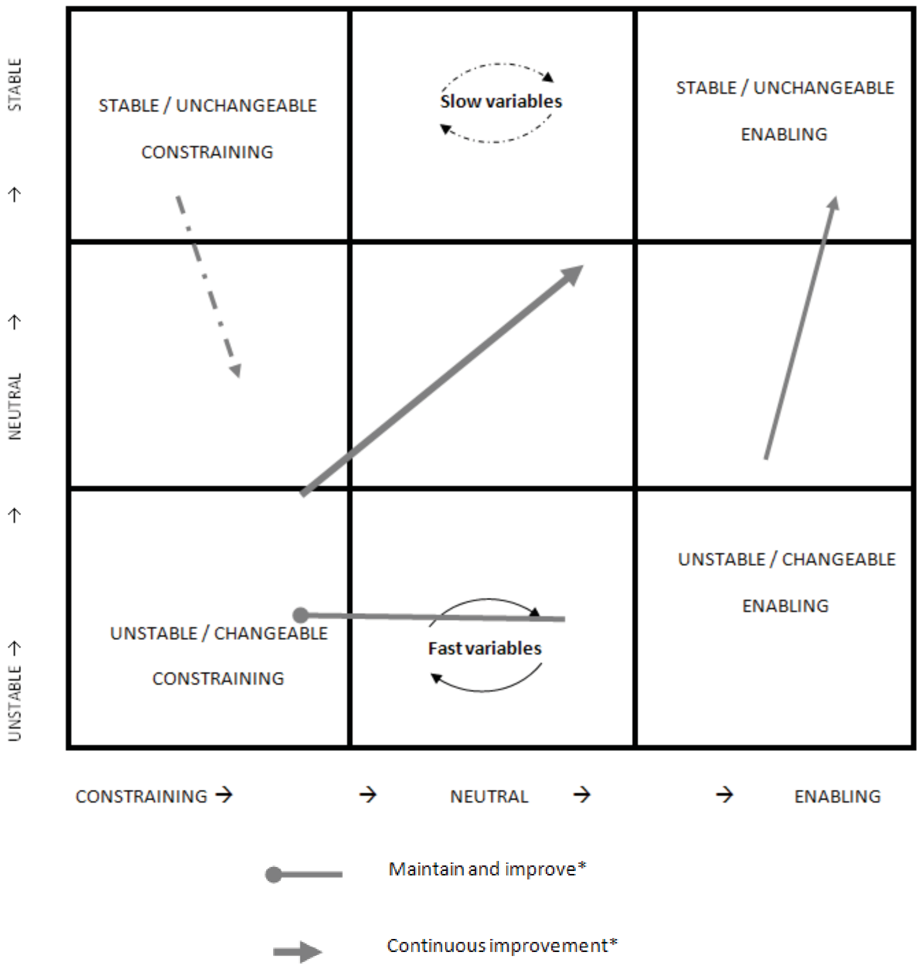


Figure 3.1: A conceptual model for thinking through prioritization of indicators for adaptive capacity. * Thickness of arrow implies priority of action. Dashed arrow implies that stability of indicator may constrain action.

3.2.2 Workshop organisation and logistics

For the regional workshops, invitations were sent to all oyster license holders in NSW, and all member ship of industry organisations in SA and TAS[1]. Snowball recruitment, due to a low initial response, was undertaken via telephone and email. People from government agencies and other organizations were also invited through snowballing. Many growers contacted in person were interested in the workshops but unable to take a day away from work, despite timing the workshops around low tide and out of peak production season. Interested people provided their email addresses and were provided an opportunity to have input into the final report via a draft sent out for comment. Only two of people contacted said they were either not concerned about climate change or they did not believe that climate conditions were change.

Regional workshop locations were designated following consultation with industry bodies and peak advisory groups, and growers themselves. The regional workshops were held in Batemans Bay and Forster (NSW) respectively on the 28th and 30th of April, 2010,; Streaky Bay and Port Lincoln (SA) on the 3rd and 4th May, 2010; and Campbell Town (TAS) on the 14th May, 2010. An example agenda for the workshops is included as in Appendix 2. The regional workshops were very successful, with keen engagement, despite relatively low attendance at some workshops. These workshops also served a linking function, building on existing collaboration, and extending some science to growers in the regions.

Following analysis from the workshops a link to the draft report was emailed to all participants and those who had expressed interest in the workshops but were unable to attend. This form of extend peer review (Funtowicz and Ravetz, 1993) enabled some clarification of issues and recommendations. In all, the report was downloaded 69 times. Comments and queries were sought within two week window, and 9 of these were received, with various detail.

3.2.3 Limitations of RCVA approach to vulnerability assessment

As with all approaches to assessing vulnerability and adaptive capacity in complex systems, uncertainties will be pervasive (Frickel and Vincent, 2007). The approach described above is a process that attempts to balance salience, credibility and legitimacy of output information in the context of budgets and timelines (Cash et al., 2003). The key sources bias, error and omission are likely to stem from the following factors:

- It is a first pass approach for institutional learning, and will thus open questions as much as it answers them. For example, many of these questions relating to the way specific projected exposure might ramify as an impact cannot be addressed with the resources available.
- It is not representative: only a small portion of all oyster farmers from each state attended the workshops. Workshop attendance was generally low, but varied between states: in NSW a total of 18 growers attended (of approximately 341 license holders, approximately 5%); in SA, 5 growers (of approximately 318, approximately 1.5%), and; in TAS 6 growers (of approximately 120, about 5%).
- There is also potential for selection bias: workshops require that individuals and businesses donate their time, and where people's livelihoods are most tenuous they will not prioritise workshops that are targeted towards non-priority areas such as strategic planning and adaptation to perceived long-term issues. Therefore representation tends to exemplify the more proactive, financially successful and least vulnerable. It is also possible that selection bias favours those who are already interested and engaged with climate change as an issue. However, only two growers contacted in the process of snowball recruitment for workshop participants suggested that they were not interested in the workshops because they thought climate change was not really happening, or that it was a 'beat-up'.

[1] Invitations were sent via the Department of Industry and Investment in NSW, the South Australian Oyster Growers Association in SA, and Oysters Tasmania in TAS.

- The workshops do not allow for detailed investigation of cultural issues, such as place attachment and identity, which often underpin how people frame their livelihood strategies and approaches to risk (Douglas, 1985; 1992).

3.3 Participation in regional workshops

In total, 56 participants attended the workshops, 33 of whom were oyster growers. The breakdown of workshop participants by occupation is given in Figure 3.2. The breakdown of attendance by age cohort across all workshops is given in Figure 3.3.

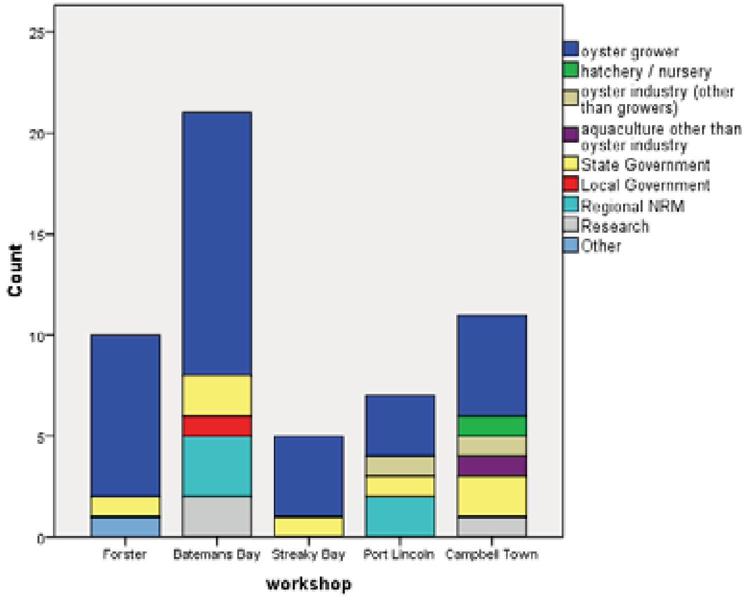


Figure 3.2: workshop attendance by occupation.

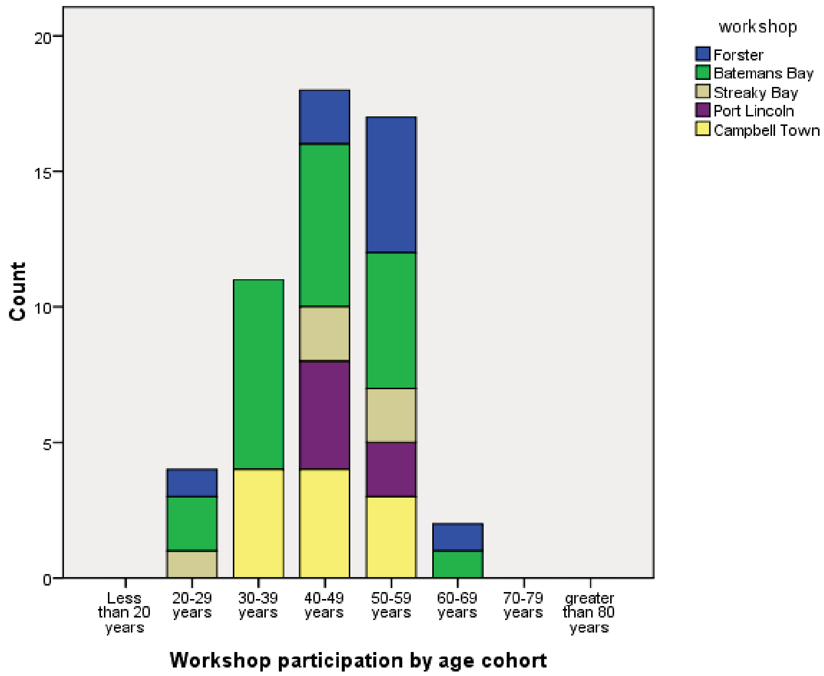


Figure 3.3: workshop attendance by age cohort

4 The edible oyster industry across jurisdictions: geography and governance of oyster aquaculture

4.1 Geography of oyster aquaculture in Australia

The geography of oyster production is marked by substantial differences across the states. In NSW and TAS, oyster aquaculture predominantly occurs in estuaries. Periodic pulses of freshwater from high rainfall events can impact on the ecological function of these estuaries, but they are also susceptible to changes in ocean conditions. Terrigenous sources often provide nutrient inputs for the food chains on which oyster production depends. In South Australia, oyster production occurs in the oceanic bays. The aridity and resulting lack of terrestrial run-off that characterises these environments creates a marine food chain founded almost entirely on nutrients from oceanic sources. This region is characterised by variable, though generally oligotrophic conditions, and substantial temperature and salinity gradients, particularly during summer in the Spencer Gulf and Gulf of St Vincent.

After growing through the twentieth century, oyster aquaculture in NSW has been in a general state of decline since the 1970s. Expanding human population and increasing demands on water resources present challenges that vary along the coastline and between years in relation to inter-annual climate variability. White (2001, pg 6) identified key issues for the maintenance of oyster aquaculture in NSW "The principal threats to oyster production are: human faecal contamination of oyster growing areas, due to expanding coastal populations, particularly in the northern part of the state; the oyster diseases QX and winter mortality (whose linkage to environmental degradation is yet to be established); runoff from acid sulfate soils; turbid waters; marine biotoxins; agricultural and industrial pollutants; and prolonged freshwater flooding. Stressed oysters are prone to diseases. Major impediments to the industry in NSW are: the institutional arrangements for the management of estuaries; the structure of the industry itself; and the availability of finance." Since 2001 a variety of initiatives have gone some way to addressing many of these issues. As this report details, others continue to persist.

Like NSW, TAS oyster farming is potentially affected by upstream sources of pollution. Although population pressure is substantially lower in TAS than in many NSW catchments, land use in catchments has potential to affect oyster aquaculture, and concern about such issues have become a source of controversy in some areas. Mortality of oyster is TAS is mostly poorly explained, but is likely to result from an interaction of environmental, pathogenic and management conditions.

In SA, the oceanic bays in which oysters are grown vary widely in terms of their productivity and the variability of key parameters. The major sources of nutrient in these system appear to be upwelling along the shelf of the Eyre Peninsula and off Kangaroo Island occurring mostly in summer (Middleton and Bye, 2007), and churning of benthic sediment through wind and wave action in the shallower gulfs and bays. Temperature and salinity in the area also vary widely, especially in the Gulf of St Vincent and Spencer Gulf. In these gulfs a strong gradient of temperature and salinity tends to develop in the summer months, trapping warmer saltier water in the gulfs, and erode during autumn and winter. These biophysical conditions and their variability remain poorly understood (Middleton, Pers.Comm. 2010), yet are the basis of oyster productivity.

The basic geography of the oyster growing environment is overlain by factors influenced by the species of oysters and breeding lines grown, both crucial determinants of how adaptation will proceed. The SRO is native to Australia's east coast and grown only in NSW and Queensland. Depending on conditions, individual oysters take 3 to 4 years to reach a size acceptable to premium oyster markets (plate grade). The PO is endemic to the Pacific coast of Asia and was introduced into Australia for aquaculture from Japan during the period from 1940 to 1970 (Medcof & Wolf 1975, Olsen 1994). In TAS and SA, POs reach plate grade in 12 to 30 months in most areas. At the most basic level, all oyster production is affected by four primary environmental variables: temperature, salinity, water quality, and food supply (Rubio, 2008).

The latter two are complex factors influenced by diverse relationships. All factors appear to operate synergistically to create preconditions for oyster health and growth, yet they may also lead to disease susceptibility. The biological sensitivity to climate change for each of these oysters is thus a complex a function of their physiology, environment and management. In Section 4.6 the current state of knowledge about each of these the two species is described in the context of climate impacts.

4.2 Governance of oyster aquaculture

Across all states, governance of oyster aquaculture involves many authorities. These can be categorised in terms of their roles relating to planning, compliance and environmental health. In NSW and TAS, in particular, where upstream impacts are potentially disastrous for oyster aquaculture, management of clean water is a critical issue for the industry. In the context of climate adaptation, the complexity of the governance arrangements can lead to institutional strength, if responsibility is well co-ordinated and networked (Ostrom, 2009). Conversely, if poorly co-ordinated, institutional complexity can result in dereliction of duty via the diffusion of responsibility. The current effectiveness of organisational arrangement in each state is reflected to some degree through the workshop dialogue with respect to the outline of governance arrangements laid out in Appendix 3.

There are substantial similarities between states in terms of how oyster aquaculture is regulated and managed. Each state has a commitment to ecologically sustainable development (ESD) enshrined in its relevant legislation. The ESD provisions follow the National Strategy for Ecologically Sustainable Development in emphasising principles of inter-generational equity, precautionary approaches, and a balance between social, environmental and economic outcomes (Commonwealth of Australia, 1992). All states specify zones (SA and TAS) or priority areas (NSW) in which oyster aquaculture can take place. Unlike the other states, the designation of Priority Oyster Aquaculture Areas in NSW creates a policy formulation of a ‘social license to operate’ for the industry as a ‘priority outcome’ in specific areas. Both SA and TAS have substantial enabling legislation and policy provisions for oyster aquaculture. The central difference between these and the NSW OISAS is that, in reaction to crises following disease outbreaks, OISAS provides wider policy recognition of the need for a whole of government and cross-scale (local, state) instrument that clarifies roles and responsibilities. Each state has a shellfish quality assurance program run through the state’s food safety authority or health department. These programs monitor water and shellfish to ensure that micro-organisms and toxic phytoplankton are within standards acceptable for human health. They are funded publicly with a variable proportion of the cost of the program recouped from the industry through levies.

Less formal aspect of institutional capacity relate to organisational cultures, workloads, resourcing, priorities, and staff capacity. These aspects of institutions are more difficult to analyse thoroughly and commentary on them in this report is indicative rather than conclusive. Nevertheless they are reflected in various ways through workshop dialogue and key informant discussions. They are indicated by specific discourse about relations and functional characteristic of process. For example, informal institutional process can have substantial impacts on the degree to which agencies can develop and maintain working relationships with industry bodies, and are thus reflected in these sorts of relationships. They are also evident in levels of trust and respect in particular government agencies among growers, and vice versa.

4.2.1 New South Wales

The NSW oyster industry is regulated primarily under the *Fisheries Management Act* (1994), with Industry and Investment New South Wales (I&I NSW) being the principle management agency. Under this Act, the NSW *Oyster Industry Sustainable Aquaculture Strategy* (OISAS) (NSW Department of Primary Industries, 2006) is the major policy document guiding development of the industry. Best practice oyster farming standards and a commitment to ESD are included in OISAS. OISAS was subject to wide ranging public industry and interagency consultation prior to gazettal. OISAS reflects a response to “rapid development of the NSW coastline” and provides “a pathway to address issues affecting the industry’s long-term survival” (NSW Department of Primary Industries, 2006, pg. 2). Thus, OISAS provides a policy mechanism for integrative and strategic planning. In supporting the industry's right to exist, OISAS aims to ensure that water quality, tidal range and flow are not compromised by development or actions either upstream or downstream of Priority Oyster Aquaculture Areas (POAA). OISAS identifies POAAs that have been assessed for their suitability against a range of ESD criteria and agreed by an interagency taskforce.

Tenure over suitable areas of water is provided by way of an aquaculture lease. The current lessee has first right of renewal. The grant of oyster aquaculture leases outside POAA requires development consent from the relevant local council first. All oyster aquaculture leases in NSW are advertised for expression of interest and an open competitive allocation process is used if multiple interests are received. Moving an oyster lease is an expensive exercise due to the high level of embedded capital. In some cases leases that become unsuitable are abandoned by the lessee. NSW has a compliance program and lease security arrangements in place to manage this issue.

An aquaculture permit is also required to authorise the oyster farming activity on the lease. Permits are issued in perpetuity, but the conditions of the permit may be amended at any time. Aquaculture permits can be modified quickly in response to emergencies or to implement adaptive responses to emerging issues. Land bases for the industry are mainly on Crown land leases administered by the NSW Land and Property Management Authority, although some facilities are on private land. Competition for available waterfront land is a serious threat to industry growth and may hinder adaption if the sites currently occupied become unsuitable.

Some 43 per cent of POAA are in Marine Parks administered by the Marine Parks Authority or Aquatic Reserve administered by the Department of Environment Climate Change and Water (DECCW). In addition there are 60 ha in National Parks and Nature Reserves administered by DECCW. Although I&I NSW have the capacity to grant leases in these areas, the objectives of the reserved area must be considered and in some instances an additional Ministerial concurrence is required.

Water quality for food safety is monitored in all NSW oyster harvest areas under the NSW Shellfish Program administered by the NSW Food Authority. Upstream impacts are addressed through the planning system with specific provisions mandating referral of certain development application to I&I NSW for comment and providing grounds for refusal of projects that cannot demonstrate compatibility with oyster aquaculture. An interagency protocol exists to respond to instances where existing development threatens or causes a downgrade in a harvest area classification. Monitoring and management of estuarine water quality is organised regionally through Estuary Management Plans, underpinned by collaboration between the state Department of Natural Resources, local councils and Catchment Management Authorities (New South Wales Department of Natural Resources, 2010). The responsibility for water quality largely rests with local government.

Applications to cultivate a new species on an oyster aquaculture lease are assessed on a risk management basis with native, locally occurring species being low risk and noxious fish (i.e. POs) or imported spat receiving a higher level of assessment. I&I NSW has protocols for the production and importation of oyster spat from Tasmania and also regulates intra-estuarine movement of oysters to control the spread of POs and QX disease.

OISAS is currently silent on climate change impacts and adaption, but is reviewed every five years. This provides an opportunity for new POAA to be assessed and made available to the industry. This review will include public and stakeholder consultation.

The NSW industry is organised through the Oyster Committee of the New South Wales Farmers Association, representing approximately 200 oyster farmers located in 30 estuaries in NSW. The Committee aims to maintain a viable industry and focuses on key issues such as production, marketing, tenure security and water quality (NSW Farmers Association, 2010). The NSW Aquaculture Research Advisory Committee (ARAC) is a statutory organisation which recommends research and development priorities for the sector broadly, which are funded through grower levies.

4.2.2 South Australia

Oyster farming is regulated under the *Aquaculture Act 2001* (the *Act*), a single, dedicated piece of legislation that governs aquaculture in the state. The Aquaculture Division of the Department of Primary Industries and Resources of South Australia (PIRSA Aquaculture) has responsibility to administer the *Act.* Advice to the Minister is provided by independent Aquaculture Advisory Committee and by the Aquaculture Tenure Allocation Board (ATAB). PIRSA Aquaculture engages with other government agencies, including the Department of Transport, Energy and Infrastructure (DTEI), the Department of Environment and Natural Resources (DENR), the Environmental Protection Authority (EPA), the Development Assessment Commission (DAC) and Native Title Claimant Groups. In particular, applications to PIRSA Aquaculture are case managed by individual employees of PIRSA who become responsible for their progression through different government agencies and processes. This, coupled with the high percentage to which PIRSA Aquaculture in cost-recovered, creates a platform for transparent process and clear lines of communication between industry and government. PIRSA Aquaculture has developed initiatives to continually reduce red-tape and streamline processes to improve efficiencies and flexibilities. Such initiatives are explicitly targeted to enable aquaculture industries to be more adaptive.

Two key elements of the management framework are aquaculture zones, and aquaculture leases and licenses. Zones delineate areas where aquaculture is deemed appropriate to use. Aquaculture leases give secure access and exclusive occupation rights on defined areas of the seabed, providing protection to the infrastructures and stock on site. Leases are issued on a competitive basis by the ATAB for those in zones and individually for those outside zones. Aquaculture licenses permit certain farming activities (be it marine or land-based) through specified licence conditions. The Minister can identify an emergency zone, within State waters, for emergency relocation of aquaculture operations grant an emergency lease. A process for granting of an emergency leases exists and is under review.

An Environmental Monitoring Program (EMP) is mandatory for all aquaculture license holders and allows for ongoing assessment of environmental performance. For the oyster industry, EMP reports must contain farm management information relating to feeding practices, chemical usage, as well as details of any known wildlife interactions and are collated and analysed by PIRSA Aquaculture annually. The South Australian Shellfish Quality Assurance Program (SASQAP) was established in 1994. The main aim of SASQAP is to provide public health protection for consumers of South Australian shellfish and thus allow the development of a sustainable shellfish industry across the state.

South Australian Oyster Growers Association (SAOGA) represents and supports the oyster industry at a local, state and national level. The industry is actively involved in the South Australian Shellfish Quality Assurance Program (SASQAP), which provides customers with confidence that the product meets stringent requirements relating to public health. In addition to SAOGA, the oyster industry is also represented by a research arm called the South Australian Oyster Research Council Pty Ltd known as SAORC, which is an industry body funded by a levy on seed sales. This allows the industry to actively incorporate research to the development of the industry.

4.2.3 Tasmania

Oyster farming activities in Tasmania are regulated by the Department of Primary Industries, Parks, Water and Environment (DPIPWE) under the *Living Marine Resources Management Act 1995* (LMRMA) and the *Marine Farming Planning Act 1995* (MFPA). The Marine Farming Branch (MFB) of DPIPWE manages the marine based component of aquaculture in Tasmania. The MFPA prescribes a planning process for the zoning of parcels of State waters where marine faring is a permitted activity. This planning process requires that draft marine farming development plans be prepared by the Planning Authority (PA) and reviewed by a statutory, independent expertise-based Marine Farming Planning Review Panel (MFPRP). The MFPRP, for a zone recommends to the Minister that a draft plan meets the requirements of the LMRMA and the Minister can approve its release for public exhibition and comment. The PA is then required to report on the written submissions to the MFPRP. The MFPRP can hold public hearings and those persons that have made written submission regarding the draft plan are entitles to a hearing. The MFPRP may require modifications to the draft development plan. Draft modifications, if required, are then exhibited for a further two months for comment. Once the MFPRP is satisfied that the draft plan meets the statutory requirements of the MFPRP, it submits the plan to the Minister recommending that it be approved. If approved by the Minister the MFDP has the effect of law. MFDPs include environmental impact assessments and set compliance obligations for leases within zones to ensure environmental, social (aesthetic, amenity, access) priorities are met.

The MFPA establishes mechanisms for the amendment of MFDPs which must be reviewed at least once every ten years. The Minister may approve emergency Plans to address short-term emergencies. Emergency plans remain in force for a period not exceeding two years, and override an existing MFDP to the extent of any inconsistency. Each development plan provides a means of protecting the environment by zoning appropriate areas for farming, providing management controls (i.e. specific guidelines for carrying capacity, environmental monitoring, disease, chemical usage and waste removal) and incorporating stakeholder opinions.

The MFB interacts with a number of agencies. The Environmental Protection Authority is involved in relation to environmental issues. Local Government and Crown Lands are involved in relation to land-based facilities. The Department of Health and Human Services is involved in relation to potential human health issues (i.e. heavy metals and toxic alga) and runs the Tasmanian Shellfish Quality Assurance Program (TSQAP) with contributions from industry via a grower levy.

Leases are granted under the MFPA which entitles the holder to exclusive occupation of the water. The leaseholder requires a marine farming licence issued pursuant to the LMRMA to engage in the activity of marine farming. Licence conditions can be varied by the minister in certain circumstances (in which case the licence holder may have rights of review and appeal) or, by application, by the licence holder. Licences are more easily varied than leases and so can enable short term adaptive strategies. Under the MFPA, provisions also exist for emergency leases to be allocated.

The management of land based activities which could impact on oyster aquaculture are the legislative responsibility of several authorities, largely co-ordinated though the Resource Management and Planning System (RMPS), especially through implementation of the *Land Use Planning and Approvals Act* (1993). The *State Policy on Water Quality Management* 1997 sets 'Protected Environmental Values'. These policies and processes provide a framework for integrated of catchment management, which is evaluated through monitoring and analysis in State of the Environment Reporting every 6 years.

The Tasmanian industry is organised through a peak body – Oysters Tasmania – a joint initiative of the Tasmanian Seafood Industry Council, the Tasmanian Shellfish Executive Council and the Tasmanian Oyster Research Council (TORC). Oysters Tasmania was formed in 2009 as the communication and organisational hub of the Tasmanian oyster industry (Oyster Tasmania, 2010).

4.2.4 Governance – concluding comment

Each state has detailed regulatory and governance arrangements for oyster aquaculture. While the broad frameworks are similar, there are also differences. The key structural differences between states lies in legislative and policy formulations that enable streamlining of processes (such as approvals or changes in permit/lease arrangements), integration and coordination of action across agencies, and mechanism for managing conflicting priorities and trade-offs (e.g. environmental protection and regional economic development). Initiatives such as the NSW OISAS provide a clear policy framework and statement on management of oyster aquaculture across diverse arenas and thereby appear to promote a relatively integrated approach. The effects of the legislative and policy formulations and differences are discussed in more detail in relation to workshop dialogue (Section 5) which shed light on the perceived function of current arrangements. Climate sensitivities and exposure in the Australian edible oyster industry

4.3 Sensitivities: Sydney Rock Oysters

Recent studies indicate that SRO embryo larvae and spat are quite tolerant of temperatures in the range 16-30^{o}C and optima for growth and development increases as development progressed, from 26^{o}C for embryos to 30^{o}C for spat (Dove and O'Connor, 2009). Growth of SROs is also affected by salinity and the range of salinities tolerated varies as a function of temperature and developmental stage (Dove and O'Connor 2007). Embryos and early larvae growth is best at salinities close to those found in coastal waters of 30-35 ppt. Embryo development was generally significantly reduced outside this range and rarely occurred at salinities of less than 25ppt (Dove and O'Connor 2007). Salinity tolerance increases as larvae approach settlement and as the oysters enter the juvenile settled stages (Nell and Holliday, 1988; Dove and O'Connor 2007). Newly settled oyster larvae are affected at salinities below 20 ppt (dove and O'Connor, 2007) and grow best at salinities within the range of 25-35ppt (Nell and Holliday, 1988). Both juvenile and adult SRO can tolerate salinities in the range 15-45ppt (Nell and Dunkley 1984; Nell and Holiday, 1988), but in general growth is best within the range 25-35ppt (Nell and Holiday, 1988). Water quality, along with salinity and temperature can have major direct impacts on oyster health and viability, but also via stress levels in oysters, can make organisms more susceptible to disease.

Cultivation of SROs in NSW dates back to around 1870 when traditional French approaches were applied to inter-tidal production (Nell, 2001). Growers quickly realised that SROs required extended tidal drying to limit mud worm infestation (Nell, 2001). Innovation improved production and output of SROs gradually increased the from NSW until production peaked in the late 1970s, when production began to decline rapidly/ This decline has continued until recently as a result of multiple environmental stressors and disease vectors. The recent innovations that have led to stabilisation of production include the use plastics to replace tarred timber on leases and highly technical approaches to breeding disease resistance into wild lines and selecting for fast maturation and growth. Breeding programs were rapidly developed following the collapse of SRO aquaculture in two major growing areas in 1994 (Georges River) and 2004 (Hawkesbury River). The disease responsible for these collapses is QX or 'Queenlsand unknown'. During the 1970s QX only affected oyster production sporadically in estuaries of northern NSW and southern Queensland. The breeding program has developed increased resistance alongside growth rates (Nell, 2007) Nevertheless, approximately 75% of SROs grown out in NSW are wild oysters harvested on sticks in catching leases near the mouths of estuaries. Breeding programs have also developed a less invasive triploid line of POs which was the basis of industry recovery following the Hawkesbury QX outbreak. Increasingly, triploid POs are being grown in other NSW estuaries.

Another legacy of disease in NSW, and particularly of QX, is that there are complex restrictions about the movement of oysters from one estuary to another. Restrictions to movement were first imposed by the New South Wales Government to prevent QX impacting on oyster growers in areas where it was not previously a problem. In more recent years, NSW DPI has entered into agreements with growers from particular estuaries whereby growers make their own risk assessments on the basis of data presented by government agencies, and are given the opportunity to take risks about oyster movement if they can reach consensus that the risk is worth taking (Ian Lyall Pers Comm. 2009). Such a co-management of risk distributes responsibility for regulating disease risk across New South.

4.4 Sensitivities: Pacific Oysters

Pacific oysters have a very wide environmental tolerance, as is demonstrated by their successful, commercial translocation to approximately 20 countries from tropical to temperate zones (Ruesnik et al., 2005). Optimal salinity ranges for rearing POs increase as they age from larvae (19-27‰) to spat (15-30‰)(Nell and Holliday, 1988). In some SA bays, a typical salinity of 41‰ coupled with summer water temperatures of 27^{o}C can curtail oyster growth irrespective of food availability (Shpigel and Blaylock, 1991). Optimal water temperatures for larval and adult growth are 25-30^{o}C and 15-18^{o}C respectively (Quayle, 1969; His et al, 1989).

In SA and TAS, POs are purchased as spat (juvenile oysters) from one of three Tasmanian nurseries. Thereby breeding lines are controlled closely and developed to suit specific conditions and markets. Wild or feral Pacific Oyster populations are considered a pest and have become established in some parts of TAS and NSW, totally covering some inter-tidal reefs. In SA, wild individuals have colonised some farming regions (Li and Clarke, 2010).

Pacific oyster mortalities appear to result largely from opportunistic pathogens that infect oysters already weakened by a combination of stress and the high metabolic cost of reproduction (Li et al, 2007; Li, 2008; Taris et al, 2009; Li and Clarke, 2010). Elevated temperature is known to be the strongest environmental predictor of the presence of marine pathogenic bacteria (Zimmerman et al, 2007). When a new combination of host and pathogen arises, the host may have innate resistance through physiological traits never encountered by the pathogen. It may also be highly susceptible to pathogen attack because selection for resistance has never occurred (Harvell et al, 1999; Forrest et al, 2009).

4.5 Sensitivities: economic

Although it is beyond the scope of this research to thoroughly investigate economic and market sensitivities and their implications for the resilience of oyster aquaculture, two basic economic parameters are indicative of aspects of resilience and need to be mentioned. Figure 4.1 is indicative of the relative scale of the oyster industry across states in terms of gross value at the farm gate. These data indicate relative stability in NSW, a slight growth trend in TAS and substantial industry growth in SA during the period from 2002-8. These data are informative when taken together with Figure 4.2 which depicts the income distribution of Rack and long-line aquaculturists (including mussel growers) form the 2006 census. These census data indicate that, across this employment class, although there are many more participants in NSW relatively fewer NSW participants in the higher income brackets, and relatively more are in lower income brackets. This may imply that in terms of labour and financial pressures the NSW rack and long-line sector broadly is less economically resilient than its counter-parts in other states.

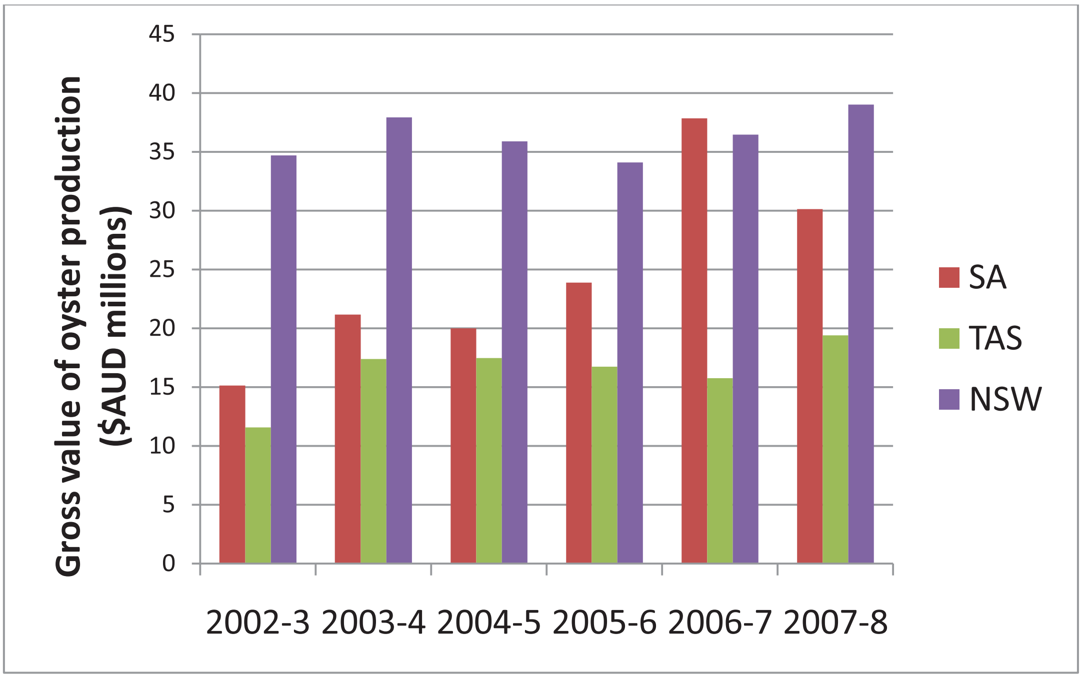


Figure 4.1: Gross value of oyster production by state from 2002-3 to 2007-8 (from data in ABARE, 2006; 2008; 2009).

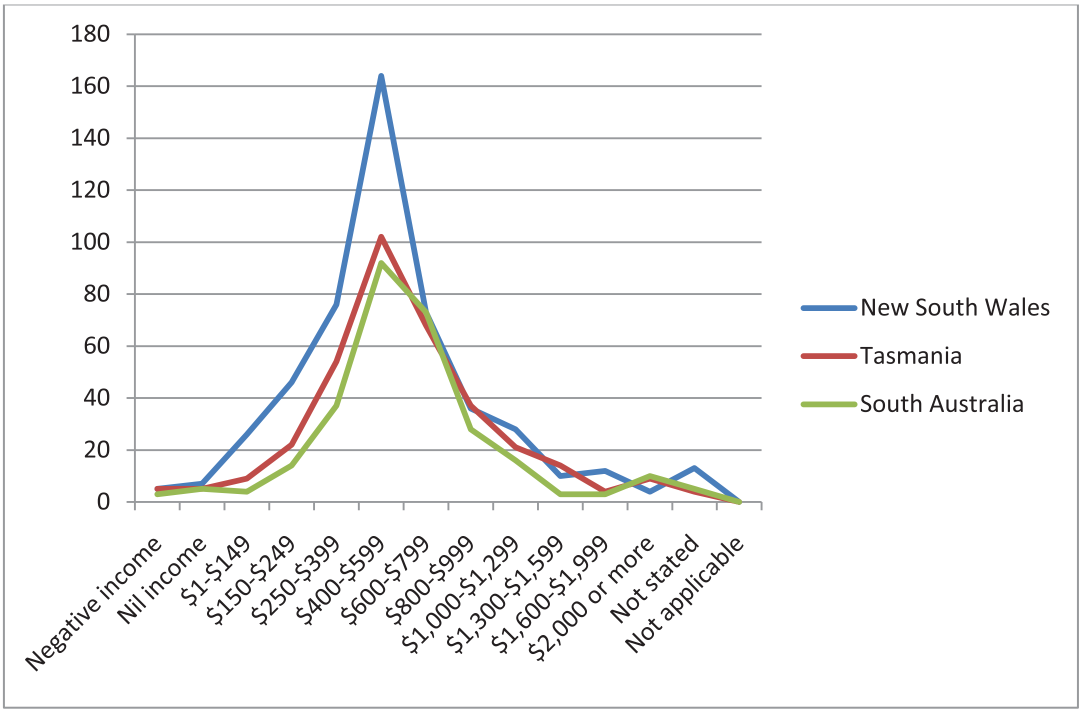


Figure 4.2: Distribution of individual weekly income by industry of employment, with the y-axis representing number of people (Off-shore Longline and Rack Aquaculture) (Data Source: 2006 Census of Population and Housing).

4.6 Climate risks and uncertainties for oyster aquaculture

4.6.1 Air and water temperature

Eastern Australian oyster leases (both POs and SROs) are bounded by a poleward-flowing warm ocean current, the East Australian Current. This currents carry warmer nutrient poor water to cooler temperate southern regions (Hobday et al, 2008). Recent trends in sea-surface temperatures are indicative of the strengthening of the EAC, and this change is projected to continue with climate change (Oulton, 2009). Theoretically, nutrient poor water will have negative impact on oyster performance. Significant reductions in the availability of silica have already been recorded off Australia's east coast and these may be contributing to changes in the abundance and types of phytoplankton (Thompson et al, 2009). However, the effects of climate changes on oceanic upwelling systems that provide nutrient to many coastal regions are not well understood and are thus poorly represented in existing models, especially in SA. Upwelling events in SA can result in SSTs dropping by approximately 2-3°C and increase in surface chlorophyll-*a* concentrations to tenfold greater in comparison with ambient water (Kämpf et al, 2004).

Both SROs and PO are cultured inter-tidally, which implies that predicted temperature changes will affect cultured oysters during both immersion and emersion. Of the two species, SROs are potentially the more tolerant, naturally occurring in both temperate and subtropical regions of Australia. Across NSW water temperatures currently ranges from 10 -30°C (Wolf and Collins, 1977) which includes the upper end of current temperature range experienced and that the current cultivation range lies well within the overall species range, potential changes in immersion temperatures are not thought to be likely to have a direct impact. However as noted later synergistic impacts of temperature and other factors need to be considered, as does the potential for other temperature influenced vectors to cause change. For instance, it is unclear if or how temperature might play a role the major diseases affecting SRO, QX disease & winter mortality. QX disease affects only SRO and occurs in the warmer northern half of the cultivation range where typically infection occurs in summer. Increasing water temperatures could extend the range the range of the disease further south, where the causative organism is found, but disease outbreaks have not previously been recorded.

A potential positive to arise from elevated water temperature would be an expected increase in growth rates of oysters in southern NSW, which currently can take more than a year longer to reach harvest size than similar stocks in northern estuaries. This however may be tempered slightly by changes in reproductive timing that is dependent on critical temperatures being achieved for reproductive development to occur. Marketability of oysters is in a large part dependent on reproductive timing, so warmer waters may affect market timing.

The cultivation of POs in NSW has to a large extent been determined by the invasive success of this introduced species within the candidate estuaries. In Europe, warming water temperatures have already been hypothesised to have impacted on the reproductive success of the species, with elevated temperatures, exceeding threshold temperatures for oocyte growth, larval development and settlement, promoting recruitment (Dutertre et al, 2010). This along with other factors discussed later may lead to greater invasive success.

4.6.2 Harmful algae

Across oyster growing areas, Harmful Algal Blooms (HABs) can make oysters unsafe for human consumption. These blooms are often triggered by complex interactions of factors including salinity, nutrient availability, and the presence or absence of particular signature molecules, making some areas particularly susceptible to their occurrence (Hallegraeff, 1992). Across all states, monitoring programs are in place to detect HABs and to close estuaries to harvest pending a bloom in order to protect human health. However, none of these programs is perfect and human illness and death have occurred after consumption of con Some algal species, such as *Prorocentrum minimum*, affect oyster health been implicated in the oyster mass mortalities in NSW (Ogburn et al, 2005). Changing ocean currents and sea-surface temperatures are increasing the spread and intensity of some harmful algal species and these range changes are likely to continue as a result of climate change (Hallegraeff, 2010). Alternatively, toxins from harmful algal species can accumulate in oysters and affect consumers. Monitoring is in place for potentially harmful blooms, however any increase in their occurrence is likely to increase both the frequency and/or duration of estuary closures. Current testing relies on microscopic examination of water samples and thus should new species occur or should altered environmental conditions lead to a change in toxicity of existing species, problems may occur that would affect consumer confidence and potentially impact on sales.

4.6.3 Acidification

CO_2 emissions are having two effects on the surface ocean via CO_2 uptake. First, when CO_2 dissolves in sea water, it forms carbonic acid which dissociates to form bicarbonate $(HCO_3)^-$ and hydrogen ions (H^+). The latter is responsible for a fall in pH and hence acidification of the oceans. Second, it will reduce the surface ocean carbonate ion (CO_3^{2-}) concentration and decrease the calcium carbonate saturation state (Hobday et al, 2006; Oulton, 2009).

Model estimates of surface pH reduction range from a drop in 0.3 to 0.5 pH units over the next 100 years and up to 1.4 pH units over the next 300 years (Harley et al 2006). Calcified marine organisms including oysters will require more energy to build and maintain calcified structures (Hobday et al., 2008). International studies have found the impact of elevations in surface ocean pCO_2 has severely reduced calcification in molluscs, with studies showing growth of Pacific oysters could be reduced by 10% (Gazeau et al, 2007). There is also evidence to suggest that elevated pCO_2 in combination with elevated temperature may worsen these effects. Australian studies have shown that increased water temperature and carbon dioxide concentrations have profound effects on the reproduction and growth of both Pacific oysters and SRO (Parker et al, 2009; Parker et al, in press). In these studies, the synergistic effects of elevated pCO_2 and temperature caused reduced fertilisation of gametes, reduced development and growth and increased abnormality of larvae of PO and SRO. Impacts were species specific and generally greater on SRO which led Parker et al (In press) to postulate that this could infer a competitive advantage for PO that may become the more dominant species along the south-eastern coast of Australia, further recruiting into estuaries currently dominated by the native SRO.

Acidification of estuaries is also affected by acid sulfate soils, which are naturally occurring sediments and soils that contain iron sulphides. On exposure oxygen by drainage they generate sulphuric acid which can dramatically increase pH locally over short time periods. Changed rainfall patterns could affect release of sulphuric acid particularly in the context of development/human activity.

4.6.4 Sea level

Under the A1F1 scenario, global sea level rise relative to 1990 is projected to be 26-59 cm by 2100 (central estimate 43 cm), with a possible additional contribution from polar ice sheets of 10 to 20 cm (IPCC, 2007). This can result in some existing inter-tidal sites becoming unsuitable for farming. While Pacific oysters can be farmed sub-tidally, these practices are not well established in Australia and are best when done in association with inter-tidal farming (Li and Clarke, 2010).

More frequent storm events due to climate change could increase mechanical damage to infrastructure and stock losses, and reduce time period that farmers can work at the sea (Hobday et al., 2008; Li and Clarke, 2010).

For both SROs and POs, existing biological information mostly results from studies on individual parameters, yet climate change impacts will be collective responses. Coupling such patchy understanding with outputs of global circulation models with course temporal and spatial resolution (Hobday et al., 2006) makes the assessment potential impacts of climate change challenging.

Traditionally the SRO industry was based on direct harvest from oyster beds and then bottom cultivation. The impact of mud worm and other diseases has since seen oyster cultivation in many areas move to the inter-tidal zone and attempt to carefully balance immersion for oyster feeding with emersion to reduce the impact of fouling organisms and exposure to pest species. Cultivation heights with respect to mean tidal exposure times can be quite specific and unique to certain areas, however comparatively small changes in emersion time can dramatically affect oyster survival. Smith et al (2000) found reducing growing height of oysters in winter mortality prone areas by 30 cm could increase mortality by as much as 52%. While increasing sea levels will necessitate the adjustment of rack height in many areas, the expected pace of change is comparatively slow (15 cm by 2030, 47 cm by 2070) and the necessary changes may be accommodated within normal infrastructure repair and replacement cycles.

Sea level changes of the magnitude expected may have little effect on lease locations in the short to medium term; however land bases may be more significantly impacted. Storm surges are expected to increase four-fold in frequency and erosion and inundation of coastal areas will increase. Currently, of the approximately 130 land base operation sites on crown land in NSW, all are adjacent to waterways. While not all land bases are on crown land, immediate proximity to waterways is an almost universal feature and availability is already a factor determining demand for lease area in estuaries. Indeed new entrants to the industry are normally required to demonstrate access to an approved land base site. Many of these land bases occur in very low lying areas. While it is difficult to determine the synergistic impacts of sea level rise and storm surge, if this were to render the use of area that was within 1m of current sea-level untenable, over 60% of the area in the surveyed leases would be lost (Wayne O'Connor, pers comm. 2010). Comparable impacts are likely in TAS, whereas SA oyster farmers tend to have land bases well above sea-level.

4.6.5 Wind speed

Predicted wind speed increases of 4% will directly impact on farming activities. Wind and the accompanying waves generated will affect the work environment and will ultimately reduce potential work hours on leases. Increased wave energy will increase stress in culture infrastructure and will affect the materials used. Beyond the direct and potentially costly need for stronger infrastructure, culture methods are to an extent also determined by the wave environment. Excessive movement ("rumbling" of oysters) can be undesirable and affect growth rates. This is even to the extent that wave barriers have been constructed to protect oysters cultivated in certain areas.

4.6.6 Rainfall

Potential rainfall changes have important implications for the estuarine oyster aquaculture of NSW and Tasmania. Projections vary temporally and spatially with respect to mean trends. In NSW a net increase in rainfall is likely in Northern NSW, and reductions in total rainfall expected along the southern coastline (Hennessy et al, 2007). In Tasmania rainfall on the east coast is projected to increase in summer and autumn and decrease in winter and spring (Grose et al, In Press).

One of the most spatially consistent patterns across rainfall projections is that there are likely to be more intense rainfall events followed by longer dry periods. This would put increasing pressure on estuarine oyster aquaculture. Increased rainfall or increased rainfall intensity will increase the impact of flood events and have concomitant demands on culture infrastructure capacity to withstand flood damage. Flooding or high flow events also often result high bacterial loads and other contaminants, which trigger temporary harvest closure of estuaries. Longer periods without rainfall could lead to decreasing average food supplies and slower growth. Projected reductions in rainfall in SE NSW and NW Tasmania have the potential result in to reduce estuarine productivity and ultimately carrying capacity. The stocking density of oysters may need to be reduced and or growth rates may be affected. These projected changes in rainfall patterns could therefore increase in the number and/or duration of closures.

4.6.7 Changes in salinity

Salinity of estuaries NSW generally ranges from 0 ppt (fresh) to 38 ppt (Wolf and Collins, 1977). Inshore habitats in southern NSW will be affected by increases in salinity levels within embayments and inlets due to increasing evaporation driven by increases in land and air temperatures and reduced rainfall. This could have impacts on oyster survival. While oysters are generally quite tolerant of salinity changes, there is strong evidence to suggest changing salinity regimes may impact upon disease processes. Epizootics of the two major diseases of SROs are affected by salinity. Where it occurs form central NSW to southern QLD, QX disease has far greater impacts in areas of reduced salinity. Although causal links between salinity and QX remain the subject of research, increased rainfall predicted for much of this area may well exacerbate outbreaks (Butt et al, 2006). Winter mortality, however is the converse. Epizootics are largely confined to central and southern NSW where outbreaks are worse in areas of elevated salinity. Anecdotally, dry winters accompany the highest mortality and declining rainfall in southern NSW may exacerbate losses.

In South Australia the evaporation rates over some gulfs and bays such as Spencer Gulf in South Australia, particularly in the northern portion during summer, will increase, leading to higher salinity and density gradients (Oulton, 2009). Increased salinity and temperature could be problematic to those oyster leases located within them.

5 Workshop results and analysis

Description and analysis of the results of the workshops are detailed in this section. We firstly briefly outline the levels of concern about climate change across workshops. Secondly we outline how growers across the states described changes in their environment. Thirdly, we describe the research priorities identified in workshops and the rationale for these priorities given in workshops. Fourth, focussing in on each state, we detail the local contextual issues which were identified as enabling and constraining adaptive capacity. Finally, we describe the cross jurisdictional patterns of indicators of adaptive capacity in order to compare among workshops and identify broad priorities for the sector in terms of developing adaptive capacity.

5.1 Climate change concern

Among all workshop participants there was strong agreement that climate change is currently occurring and an important issue for the oyster industry. Responding to the statement "climate change is happening now", approximately 46% strongly agreed, 33% agreed, 15% neither agreed nor disagreed, and less than 2% disagreed. Comparably, approximately 74% of participants either agreed or strongly agreed with the statement "I am concerned about the impacts of climate change on the oyster industry in my area"; to which 18.5% neither agreed nor disagreed, and slightly less than 4% disagreed. Participants were in less agreement when it came to attributing climate change to human action. Only 13% strongly agreed with the statement "climate change is largely caused by human activity", with 43% agreeing, 33% neutral, and slightly less than 6% disagreeing.

In the regional workshops, participants were able to generate their own Likert scaled questions to ask of their peers, and one of was applied across workshops: "I am optimistic about the future of the oyster industry in my state". There was strong agreement to this, with 75% either agreeing or strongly agreeing, while just over 9% were neutral, less than 2% disagreeing. Results were comparable across workshops.

5.2 Observed system changes

Across the regional workshops, oyster growers were generally reluctant about defining specific changes in the biophysical system, and even more so about ascribing these to climate change. Participants often said that trends were hard to distinguish, variability was often high and that historical conditions were either unknown, or that extremes had been experienced at different times in the past. Also a great deal of local variability in changes was described, indicating that, although changes had occurred locally, they were rarely considered as shifts because they were not geographically uniform. Nor were changes generally based on measurements of records, but on anecdotal observations and discussion.

Nevertheless, especially in NSW and TAS, changes that were noted by growers that cohere with scientific observation of change and with climate change projections[2]. In particular, participants noted warmer ocean temperatures for longer durations over recent years or decades. In some cases these changes were associated with changes in marine species, including algal species. In NSW, a lack of storm conditions and associated floods and high seas had led to the closure of some estuary mouths and high rates of deposition in channels. In both NSW workshops growers also stated the widespread belief that oysters are not growing as well as they did in earlier decades. In some areas of NSW and TAS, sea-levels were suggested to have risen and accordingly racks had been lifted when they were replaced.

---

[2] The session on observed changes was held prior to the presentation of climate change impacts in order to avoid biasing of observations. Nevertheless, such bias may have been generated through other exposure to climate change information, but the high levels of scepticism about the permanence of particular changes (i.e. that they may be normal variability) indicates that many growers have minimal commitment to climate change creating trends in particular environmental conditions.

SA growers had observed that unexplained mortality was increasing in some areas, but that productivity appeared to have increased slightly and with it there was a greater fouling of weed and barnacles. Water temperatures in winter were considered to have warmed slightly in some areas.

There were also a few observations which are counter to projected impacts of climate change and, in some cases were described as instilling doubt that human-induced climate change was a real concern. For instance, growers in NSW and SA described low tides being often lower than those predicted in tide charts. In SA and NSW such low tides coinciding with hot days pose a risk to oyster health or survival.

5.3 Adaptation research priorities across workshops

Across the workshops a variety of similar questions were raised as priorities for research. It was evident from these discussions that participants were interested in developing a better understanding of the biophysical drivers of change and productivity in the bays and estuaries on which their livelihoods depend. These research priorities have a particular focus on climate change adaptation and need to be considered in this context by research advisory committees.

5.3.1 New South Wales

Key research priorities in NSW related to improving understanding of estuarine systems, their variability and the impacts of both meteorological events and human management of land and water on oyster aquaculture. The continuation of breeding programs to develop more disease resistance in oysters was also seen as a priority, as was research and development to ensure new strains of oysters would be more resilient to acidification. The ways such research questions were posed and prioritised in workshops are outlined in Tables 5.1 and 5.2, for the Batemans Bay and Forster workshops respectively. Continued efforts to develop Environmental Management Systems (EMSs) were promoted as a useful source of knowledge, and advancement of local enterprises and industry.

Table 5.1: Research priorities for adaptation in the edible industry as discussed in the Batemans Bay workshop.

Batemans Bay	
Research priority (not ranked)	**Rationale**
Research on effects of rainfall changes on streamflow	It would be useful to understand how rainfall scenarios might affect the flow of nutrients and estuarine health.
Breeding programs for improving oyster genetics	Stock resilience is the key to adapting to change.
Assessment of impacts of river and land management on oysters	This requires studies at an estuary scale to monitor impacts in areas where management appears to be effecting oyster health or growth.
Assessment of future productivity of areas	Risk analysis is needed for thinking about future movements or translocation of farming
Automatic monitoring programs for salinity, temperature and acidity to develop long term data set	The development of efficient and effective monitoring programs with co-ordinated systems and data repositories will help to understand the risks to oyster aquaculture and change in the system.
Research on stocking densities in relation to food availability (type and abundance)	Need to understand baseline conditions of food availability and how this relates to stocking in order to adapt to changing conditions

Table 5.2: Research priorities for adaptation in the edible industry as discussed in the Forster workshop.

Forster	
Research priority (ranked from highest to lowest priority)	**Rationale**
Analysis of currently collected data to better understand determinants of oyster growth.	Growers want to know what makes oysters fat. Monitoring food content in water would be very useful. Routine programs don't record the algae that leads to growth. Don't know why particular algae are there at certain times, and what has the effect on growth?
Gut analysis gives a picture of what oysters are eating	Part of developing baseline knowledge of what food makes oysters grow will be important to understanding impacts of any change.
Selective breeding programs	A useful long term strategy is to develop breeding program especially to deal with disease. Also potential to adapt to temperature through developing oysters that are more able to grow in warmers conditions.
Climate effects on algae distribution	It may be possible to compare estuaries by latitude (and think through changes if environmental conditions are moving south). But estuaries have quite different conditions so this would require careful research.
Research on environmental impacts and benefits of oyster aquaculture	In order to improve industry and its social license, improved understanding of the environmental function of oyster farming would be useful. It would also provide baseline of ecosystem services and functions in relation to oyster farming and other fisheries.
Complex systems analysis of feedbacks from climate change response (societal changes, tree/sea change, urbanisation, land management practices)	Need to recognise complexity of system in analysis. What are the key pressures and how are they changing? More or less pollutants, agricultural spray , sewerage, urbanisation?
Environmental precursors of disease	Need to complete understanding of life cycle for QX to understand drivers of outbreaks.
Acidification impact on growth	Understanding might be developed through acid sulphate effects as surrogate for acidification.
Monitoring program in Hastings to establish carrying capacity	This is an existing research project which links flow to productivity and growth rates. Some of the data may be able to be extendable to other system (probably not lakes) -- this is part of EMS program.

5.3.2 South Australia

In the SA workshops research priorities were comparable to those in NSW. The details of the priorities from the Streaky Bay and Port Lincoln workshops are in Tables 5.3 and 5.4 respectively. Oyster genetics and physiology were described as central to the development of strains of POs that would be adapted to emerging conditions. Again, in both workshops regional monitoring programs were described as imperative to understanding the pre-cursors of disease and productivity, not only for the oyster industry but for other sectors for which these environments are nurseries or have important biodiversity values. In the Port Lincoln workshop, participants also expressed the need for research to be effectively extended to growers and industry in ways that were useful and useable. It was suggested that economic efficiency of adaptation options could be built into later iterations of the Oyster Consortium Benchmarking Program.

Table 5.3: Research priorities for adaptation in the edible industry as discussed in the Streaky Bay workshop.

Streaky Bay	
Research priority (not ranked)	**Rationale**
Oyster genetics and breeding for climate change	Need to ensure breeding lines are the best for conditions as these conditions emerge or are predicted.
Regional monitoring program	Monitoring in each bay should allow for development of baseline of water temperature, pH, salinity, Ca++, and sulphate . This might be targeted to an innovative solutions projects (FRDC). Questions relate to changing water quality and variability, could be integrated with SAIMOS. Bays have public interest as nursery for significant fisheries and biodiversity.
Improving management practices through field trials	Experimental farming practices, cases studies, and doing work on shell density -- field trials, could be associated with genetic work. Documenting the effects of different farming practices. E.g. Rack heights, density, technology usage.
Physiology in extreme events	Exposure of oysters to different extreme conditions to understand responses of different breeding lines and life stages (larval stage, spat and adult).

Table 5.4: Research priorities for adaptation in the edible industry as discussed in the Port Lincoln workshop.

Port Lincoln	
Research priority (not ranked)	**Rationale**
Extension of research that may have relevance across sectors needs to be improved	Research on upwelling and effects of ENSO on productivity may have implications for oysters and other sectors. It needs to be communicated in ways that can be understood by practitioners. MISA looking into invigorating extension for marine users.
Understanding basis of food-chain and change	SASQAP has understanding of what food is available and when. There are preliminary discussions about better integration of marine datasets: alot of ad hoc monitoring has happened. (Food types effect taste of oysters, and there may be linkages here for marketing?)
Sea-level rise potential to change zoning and leases	Long term planning may be necessary and research around strategic movement of zones could be helpful.
Breeding and genetics	Seafood CRC organises much of the research. Rated as top priority -- better product and faster growth and prepared for unusual events. Spawning cycles might become a focus.
Relative advantage for marketing	Changes in production and what is being produced and where: both nationally and internationally.
Potential impacts of diseases, pests and HABs	Marine pests and HABs have potential to move or thrive in changed water conditions. Currently limited understanding of what these changes will be but could be crucial to the workings of bays.
Economic analysis of adaptation measures	Benchmarking the effects of different strategies on short-term and longer term economic outcomes would be useful to evaluate them.

5.3.3 Tasmania

The Campbell Town workshop highlighted the importance of effective monitoring and research to understand the processes of algal productivity in oyster growing environments (Table 5.5). In the context of range extensions of HABs, it was suggested that TASQAP and other programs need to keep a watching brief on which species are moving. The need to understand climate impacts at different scales was seen as requiring specific research. There was a recognition that the complexity of estuarine systems would mean that research would not necessarily apply precisely to all areas but that it might help to inform general ‘rules of thumb’ that could improve management decisions. There was also concern that research should ensure that issues resulting in hatchery mortality are addressed.

Table 5.5: Research priorities for adaptation in the edible industry as discussed in the Campbell Town workshop.

Campbell Town	
Research priority (ranked from highest to lowest priority)	**Rationale**
Understanding of inshore (algal) productivity under different climate scenarios	There may be substantial research but little understanding of implications of climate change on life stages of oyster in terms of productivity. There may be changes in nutrient condition associated with changes in EAC and upwelling conditions. Different water for different stages of production. May be able to develop applications oriented science (but this may not be at the level of peer-reviewed knowledge). Seafood CRC benchmarking study -- could form basis of a biophysical approach, we need to link the financial numbers and biological, and this needs to work across seasonal and inter-annual variability. It also would require funding over long period. Ana Rubio's work indicates that these relations are highly variable between locations. Environmental flows and seston have enormous implications. The projects need to be evaluated in terms of changes and outcomes.
Emerging species, especially HABs	TASQAP and national species range extension program need to monitor species range and augment species hit list as species move
Understanding local/regional effects of broad scale changes	Need to understand change at local and regional scale in order to act on changes, either through monitoring or reliable prediction.
What drives larval mortality in hatchery?	understanding the mechanisms that lead to hatchery problems could improve stability to supply of spat
Developing rules of thumb for management	In terms of maintaining or increasing productivity, what do growers need to know in order to grow into future? What forms of flexibility and risk management are available? Information from research needs to be applicable and well extended.
pH impacts micro-algal population	Understanding how pH changes will affect the base of the food chain may become important
What are the implications of climate change for marine vibrios?	Vibrio may be a sign of system function and animal health but may not be as substantial a pathogen as made out. What is it that predisposes animals to get vibrio? Need to understand physiology to establish if vibrio are cause or effect? They appear to becomes opportunistic to particular nutrient and temperature conditions, and can take off when there is decomposition in system (for instance in hatchery situtiaons, cleaner lines suffer less impacts).
pH and reduction of natural recruitment (oyster overcatch)	The effects of pH on recruitment could affect overcatch on leases in a positve or negative manner and also impact on feral oyster populations
Is sequestration an issue for oyster aquaaclture?	Does bio-sequestration have implicaitons for carbon trading or branding? This might be a useful avenue to explore for the indsutry.

5.4 Adaptive capacity – Local and regional issues

Because much adaptation occurs at local and regional scales it is crucial that any intervention to enable adaptation takes heed of context-specific issues that affect particular localities (Kates et al, 2001). Such local specificity also requires substantial attention to detail in order to develop knowledge that is locally relevant and can enable changes in local management. Participants in regional workshops often stated that each estuary or bay is different and will therefore require unique monitoring to understand its function and management to improve growth, health and survival of oysters. Yet it will also be important for monitoring programs to produce datasets that are comparable across regions.

In this section, the workshop discussions relating to adaptive capacity are presented for each state along with the ratings of adaptive capacity indicators. These tables with indicators, key pressures and collective actions are a direct reflection of workshop discussions and thus present the critical engagement of growers in thinking through issues of adaptive capacity. Many issues reflect personal and group opinion or perceptions and are not necessarily substantiated claims. Nevertheless, these issues represent or key concerns for growers and are thus important considerations. As a first pass assessment of adaptive capacity, many of the issues raised in workshops may require further substantiation and clarification at local and regional scales. The indicators are coloured in tables to reflect how they were rated on the two dimensions described in Section 3.1.2 and outlined in Figure 5.1. The data that form the basis of these classifications are included in Appendix 4, which indicate marginal difference between the rating of indicators among oyster growers and the entire workshop group in most instances.

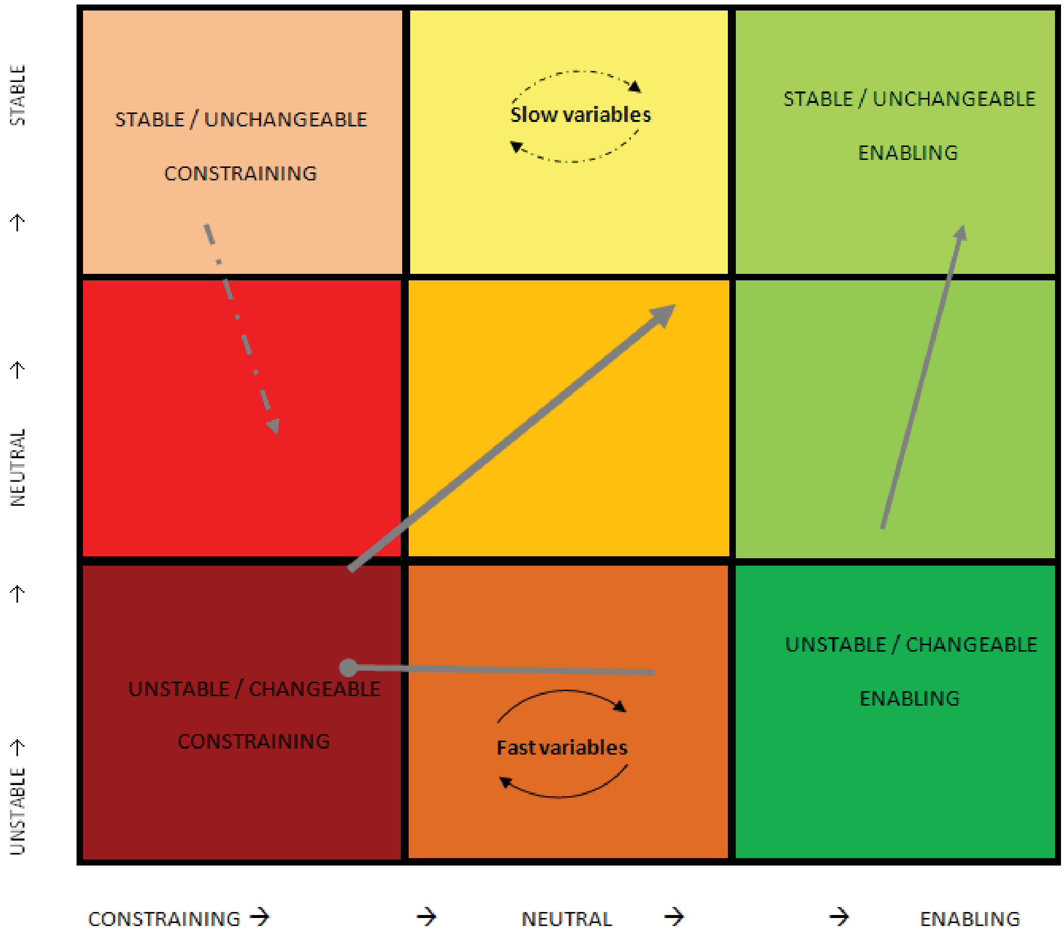


Figure 5.1: Conceptual model for thinking through prioritization of indicators for adaptive capacity (as detailed in Section 3.2.1) showing colours included in tables in this section.

5.4.1 New South Wales

The two workshops in NSW identified indicators of adaptive capacity that reflect the similarities and differences between regions. Tables 5.6 to 5.12 outline the tenor of the discussions in Bateman's Bay and Forster. Indicators identified as were often rated as constraints to adaptive capacity. These ratings reflect relatively high levels of concern among participants at the NSW workshops about maintenance and improvement of conditions for oyster aquaculture, especially in terms of biophysical conditions.

Many indicators from across the capitals were considered as constraining adaptation, especially in the Batemans Bay workshop. Yet while indicators were often rated poorly, much of the discussion also focussed on potential to develop the industry in proactive ways through improving support for industry leadership, through enhancing partnerships between growers and local governments, regional NRM bodies and state government agencies. Much of the focus of discussion about how to improve conditions for the sector emphasised collaboration and partnership, especially to ensure maintenance or improvement of water quality. Limitations of the industry to engage proactively were described in both workshops as, in part, the result of the culture within the industry which was variously described as apathetic, conservative and individualistic. These sorts of widespread human constraints were partially countered by commitment and leadership of a small but well-integrated group of industry and opinion leaders in the sector. The future resilience and capacity of the industry-at-large was described as being dependent on encouragement and mentorship of younger growers. Engagement with research and governance on behalf of the industry was in the hands of few leaders who are time constrained. The uneven distribution of workload for such engagement was described as encumbering the further development of leadership – current leaders have little time to foster skill or mentor younger growers. However, there was also recognition that, while industry initiatives were often not vocally supported by a groundswell of growers, neither were they undermined by competing interests within the industry. In both workshops there was substantial optimism about the future of the industry, and this was buoyed by strength of local and industry networks and communication.

The priorities for collective action, detailed in Tables 5.6 to 5.12, suggest that participants are keen to continue to develop networks and knowledge in order to encourage better management of estuaries, and to understand the effects of biophysical conditions on oyster growth and health. A key element of this is improvement and integration of monitoring programs and utilisation of currently available data to better understand baseline conditions and risks associated with variability in physical and chemical conditions. Suggestions about streamlining interactions between growers and government were seen as a priority in both workshops, as was development of communication within the industry to promote best practice and industry initiatives to improve community perceptions of the industry and its role in environmental management and regional economies. In the Batemans Bay workshop the positive interactions between industry and the Southern Rivers CMA were promoted as a key to building adaptive capacity through regional collaboration.

Table 5.6: Indicators of adaptive capacity for Human Capital from Batemans Bay workshop, including key pressures and collective action priorities.

Indicator	Importance of indicator	Priority collective actions
Human Capital (*the skills, health & education that contribute to the capacity to manage natural resources*)		
Individualism in industry	The degree to which individuals in the industry are looking after their own interests can limit action across the industry. This appears as inability to change and resistance to change.	High levels of individualism are counter-acted by people within the industry who are actively engaged with progress and change in the sector.
Conservatism	Conservatism was described in terms of the tendency of some growers to sit on the fence and wait to see what happens. It was relayed as a cultural trait that supports a risk averse approach and can constrain innovation and preparedness for change.	Industry could promote innovation and adaptation through showcasing examples of growers being proactive.
Support for leadership	There are relatively few industry leaders who take on a substantial voluntary workload. Those who do therefore have little time to support and mentor emerging leaders.	Support for leaders and mentoring of emerging leaders could be improved at a regional level by growers and their groups. Coordination of programs could also be improved, such that industry, CMA and government initiatives are mutually supported. CMAs plays a particularly important role in facilitating and supporting leadership.
Time constraints	Pressures on people's time came from different quarters: the need to work with tides, the many tasks relating to compliance and regulation, and the lack of profitability and available labour leave much of the work burden to managers.	Improved time management skills for growers.
Lack of skilled labour	There is a current lack of specific training for oyster industry. A general course is not enough to provide the necessary skills in an increasingly complex industry. Oyster farm work has historically been viewed as a job of last resort but this is changing. Because much of the work is casual it is difficult to develop and maintain skilled workers. Training requires substantial resources in order to comply with specific OH&S and other regulations.	Industry could improve marketing to school leavers. But growers need to find ways of developing careers for young people and training them up to be managers.

Table 5.7: Indicators of adaptive capacity for social capital from Batemans Bay workshop, including key pressures and collective action priorities.

Indicator	Importance of indicator	Priority collective actions
Social Capital (*the family & community support available, & networks through which ideas & opportunities are accessed*)		
Communication with industry	It is difficult to engage across industry as growers are dispersed across large areas and many do not use modern ICTs. The Southern Rivers CMA has improved local understanding and trust and built better linkages between growers and at least some parts of government.	Trust issues about the source of information are important and need to be considered in communication strategies. Sources need to be clearly identified. NGOs can be thought of as more trustworthy than government agencies. The CMA has developed good working relationships with many growers. This relationship should be fostered.
Government engagement strategies	Farmers often feel swamped by the number organisations they have to engage with in the normal operation of business. Various agencies have a role in regulating aspects of the oyster farms, and compliance costs can be high. Some agencies have roles in regulation, advocacy, developing innovation and information provision.	Formal mechanisms of consultation exist and the state government has legitimate processes in place. Growers and industry could develop more co-ordinated formal approach to influencing policy process. There is potential for government agencies to make better use of extended communication networks including CMAs.
Data collection and collation	Data needs to be accessible, useable and useful to help increase understanding of system and improve management over time.	There is potential to develop automatic monitoring of physical data relating to streamflow and estuary water quality. This could be incorporated into current Bureau of Meteorology datasets and would help to understand baseline conditions and impacts.
Farmers ability to engage in decision-making	An upshot of the human capital constraints to adaptive capacity, particularly time constraints is that farmers have limited ability to engage in decision-making. This refers to business decisions that require research and investigation and policy decisions a local, regional and state level. The imperative of work constrains farmers ability to engage at a higher level in management.	See issues relating to Human capital.
Industry engagement with broader community	The view of the industry by the broader community is crucial to the development and improvement of the industry. Media attention is often given to negative issues and the industry is generally not proactive enough about publicising the proactive work it is doing to ensure clean water and improved catchment management.	Collection and collation of baseline data and Catchment Action Plans allow for improved engagement on the positive ways in which the industry and growers. Programs to develop Environmental Management Systems are also examples of developing capacity for environmental stewardship and social responsibility.

Table 5.8: Indicators of adaptive capacity for natural capital from Batemans Bay workshop, including key pressures and collective action priorities.

Indicator	Importance of indicator	Priority collective actions
Natural Capital (*the productivity of land, water & biological resources from which rural livelihoods are derived*)		
Access to water / environmental flows	Flushing of estuaries with fresh water appears to be an important factor that limits the severity of winter mortality. In some areas environmental flows have reduced due to seasonal conditions and human pressure on freshwater resources. This means that some estuaries have experienced more saline conditions. moving towards POs in some estuaries.	If the need to grow oysters in increasingly saline conditions continues to prevail, culture of POs and winter mortality resistance SROs may allow continuation of oyster aquaculture in these areas. Investment in 'single seed' strains that are resistant to winter mortality is a priority. Improvement and maintenance of environmental flows are paramount in some areas.
Water quality	Water quality is many-faceted -- toxicity, ecological, food availability. A lot of different councils and authorities have impacts on water. Environmental services provided by mangroves, saltmarshes and other vegetation communities buffer water quality but may be adversely affected as sea-level rises if their lateral movement is constrained (for instance, by development).	CMA has developed Catchment Management Plans with all stakeholders. Demonstrating the value and effects of upstream actions will continue to be important and will need to be supported by industry and government, especially through the CMA. This will depend on adequate monitoring of
Inundation of land bases	Oyster land bases are potentially very expensive to remove and replace. There is some provision for rezoning as climate change proceeds.	See below actions for Identification of suitable land bases.

Table 5.9: Indicators of adaptive capacity for physical and financial capital from Batemans Bay workshop, including key pressures and collective action priorities.

Indicator	Importance of indicator	Priority collective actions
Physical Capital *(the infrastructure, equipment & breeding improvements to crops & livestock that contribute to rural livelihoods)*		
Seed stock resilience	lines of SROs with resistance to disease are being developed, but this process is gradual and cannot produce the 'super-oyster'. Genetics needs to be seen in the context of environmental conditions and management.	Continuation of breeding programs was seen as crucial.
Identification of suitable land bases	Identifying new land bases has not occurred and was described as impeding the development of the industry.	The Department of Lands, Local Government and growers need to recognise OISAS commitment to identifying land bases and Work Plans agreements for their Management.
Availability of seed stock	Current ability to catch wild stock or obtain 'single seed' stock is limited and variable. Supply is difficult to ensure and following mortality events restocking can be difficult.	None suggested
Financial Capital *(the level & variability of the different sources of income, savings & credit available to support rural livelihoods)*		
Profitability of operations	The lack of profitability in the industry make expansion difficult, especially because the costs of infrastructure for upscaling a business are very high.	None suggested (see below)
Valuation of leases as capital	The historical inability to borrow against the value of leases mean that it is hard to build up a business. Farmers must borrow against privately owned property such as family homes in order to develop their business.	Banks, industry and the State Government (Department of Industry and Investment) need to find an appropriate arrangement for borrowing against the lease and on the basis of historical business profits.
Fairness across supply chain	The profitability of oyster growing is partly constrained by the number of people and processors between growers and consumers. Farm gate profits are insubstantial compared to wholesale and resale profits. Co-operative structures set-up by growers have historically been difficult and often failed. They require substantial transaction costs, are likely to be once in a generation opportunities.	There is potential for co-ordination and co-operation among growers but this will require substantial logistical support to develop effective accountability, transparency and governance arrangements to ensure their success. Industry and Government could develop protocols for their development and support structures to help ensure their success in future.

Table 5.10: Indicators of adaptive capacity for human and social capital from Forster workshop, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Human Capital *(the skills, health & education that contribute to the capacity to manage natural resources)*		
Education and training	The experience and local knowledge of growers gives them a good basis for farming, but there is increasingly a need for technical knowledge and computer skills, which are often lacking.	If there is well-targeted and useful information available online, it would be likely to be used. Web site freely accessible for posts of best practice (e.g. Facebook). Computer training and business training could follow the recognition of need, then people will be encouraged to come along to meetings.
Apathy	Many oyster growers are part-time, or older people who do not contribute much to the industry as a whole. Many growers are not interested in thinking about the future of the industry or working collectively.	Greater recognition among growers and industry of the value of contribution and working strategically for the future of the industry.
Time constraints	Because of large workloads people's ability to participate in any initiative is restricted. It is closely linked to profitability as well as availability of labour.	Largely linked to financial viability, but there is potential to improve through better time management.
Age / time in industry	There are advantages and disadvantages of having an older industry with many of growers having been in the industry for decades. Young people can be more enthusiastic about embracing change, but this is not always the case and may be detrimental if people adopt innovations that don't work. Many of the old-hands have a sound knowledge of what can be done and what cannot.	There are opportunities to use peoples experience and knowledge. Networks among growers help to share knowledge but these could be better organised by local grower groups and industry generally.
Social Capital *(the family & community support available, & networks through which ideas & opportunities are accessed)*		
Perception of oyster industry/aquaculutre	The general public and other industries see the oyster sector as small and insignificant yet it is often more substantial than agriculture within council areas.	The industry needs to work to market the environmental credentials of the sector and emphasise the economic benefits to regional economy. Development of EMS and involvement in the marine stewardship council are important for these outcomes.
Coordination of governance	Regulation by multiple agencies makes it difficult to be able to respond to government, especially proactively. Growers are overloaded with regulations, impacts and interactions through compliance.	Coordination of regulation is important and might be achieved through a centralised point of interaction with government.
Interaction between growers	There is increasing coherence within industry and good networks. These help with coordination of responses to issues.	Coordination and networks might be further developed through online interaction and development of internet based resources/portal for oyster growers and other to share and develop knowledge.
Industry-government relations	Government and industry need to be able to work together for future of industry. Better relationships and more confidence in the relationship between industry and government departments are crucial to this.	The interactions between government and growers could be improved if growers had to deal with a single agency rather than many (i.e. a one-stop shop). Communication streams could also be improved.

Table 5.11: Indicators of adaptive capacity for natural capital from Forster workshop, including key pressures and collective action priorities

Indicator	Key pressures	Collective action priorities
Natural Capital (*the productivity of land, water & biological resources from which rural livelihoods are derived*)		
Estuary health	Estuary health includes water chemistry, pH, disease prevalence, pollution, parasites and harmful algal blooms. These all affect oyster aquaulculture in diverse and sometimes unknown ways (see section on sensitivities).	A variety of initiatives are needed and need to continue to ensure estuary health in the context of changing climate conditions and increasing population: stormwater polishing, wetland maintenance, riparian zone improvement. Local government has an important role -- Great Lakes Council has river improvement plan (which considers climate change) and they are proactive in managing water quality in Wallis. Improved stakeholder support for these programs is required. Other Councils don't implement their plans and issues vary widely across areas. There are problems of competition between agencies to get remedial work done and a lack of partnerships vertically between tiers of government. A crisis can improve estuary health and needs to be used effectively.
Water purity	Food safety (bacto and biotoxins)	Good partnerships are needed to deal with bacto-toxicity and manage bloom precursors -- e.g. stormwater, development, other issues relating to nutrient load, especially sewerage, cattle and other agriculture. Farmers are currently unregulated and this can lead to toxins entering waters.
Frequency of heatwaves	Heat stress kills oysters, especially when there is less water and they are full of roe.	Change practices: spraying and use forecasts for heatwaves could help.
Primary productivity in estuary	The primary productivity in the estuary is the basis of the food chain and is an important determinant of potential growth and stocking rates.	Monitoring algal growth and abundance and environmental management

Table 5.12: Indicators of adaptive capacity for physical and financial capital from Forster workshop, including key pressures and collective action priorities

Indicator	Key pressures	Collective action priorities
Physical Capital *(the infrastructure, equipment & breeding improvements to crops & livestock that contribute to rural livelihoods)*		
Adoption of new infrastructure	Infrastructure is expensive to change and the large investment requires careful consideration of costs and benefits over the life of infrastructure.	Growers need to know what tis going to happen in order to adopt best fit technology and techniques.
Choice of product	Current use of SROs may become less profitable if conditions change. POs, angasi, milky oysters, (other options may	Review of regulations to enable options (e.g. cockles, angasi, etc..)
Relocation of product	Highway oyster farming and potential to move between and within estuaries exists to some degree. Moving leases can be difficult in some areas, but large movements (e.g. Upstream migration) may be possible. Science-based decisions needs to back up need for movement.	Disease control limits capacity to move (i.e. there are controls around movement that are hard to avoid).
Financial Capital *(the level & variability of the different sources of income, savings & credit available to support rural livelihoods)*		
Financial overheads	Oyster aquaculture has increasing overheads relating to more regulation and compliance costs, greater transaction costs of dealing with increasing number of government agencies, greater infrastructure investment. Higher levels of required business and risk management also generate transaction cost increase.	Benchmarking project indicates compliance costs are not great (on average) but need to be considered in relation to other costs and income (i.e. small operators pay relatively more and thus are more impacted)
Profitability	May become more variable over time (if biophysical conditions change). However, these may also be countered by changes in global availability of protein which could build marketability.	None suggested
Protection of industry investment	OISAS goes some way to protecting industry, but management of leases and land bases are affected by previous decisions of previous departments, and are often changed under new governments and arrangements.	Security of tenure on landbases is essential for industry.

Taken together these workshops indicate priorities for developing adaptive capacity relating to the following key concerns:

- Improving partnerships and actions to ensure water quality and estuary health, underpinned by effective, well-integrated monitoring programs. These include linkages between Catchment Management Authorities and growers, continuation and development of programs encouraging Environmental Management Systems, co-ordinated development of monitoring programs which will allow understanding of baseline conditions and local variability.
- Developing Industry-community relations through and improving the social standing of the industry.
- Increase the human capacity of the sector by promoting leadership and proactive engagement.
- Social learning through the building better linkages among growers (to take advantage of substantial experience within the industry) and by better linking scientific and government agencies to growers (through improved approaches to communication and establishing a web-based portal).
- Ongoing improvement of existing arrangements, programs and structures to ensure efficiency by reducing red-tape and duplication of work, and that there is good coordination across government agencies.

5.4.2 South Australia

The South Australian workshops highlighted key concerns of growers about adaptive capacity and resilience. In terms of human capital, SA participants indicated that a reason for low turn-out at the workshops was likely to be the perception that climate change was having (and would continue to have) little effect on this area. Relatedly, there are low level of confidence associated with many climate impacts in this region, including changes in upwelling patterns and nutrient availability. Nevertheless, a variety of issues were identified which were considered to consistently underpin adaptive capacity across the two workshops (Tables 5.13 to 5.16). Human constraints were largely related to the poor ability of the sector to attract skilled and unskilled labour, and related issues around planning for the development of enterprises and succession, especially in the context of an aging grower population and a tendency for the next generation to be uninterested in oyster farming. Social issues were described in terms of the linkages and relations within industry, between industry and PIRSA Aquaculture, among industry bodies and growers, and relating to the community perceptions of oyster farming. Natural capital indicators related to the biological basis of productivity, and physical capital indicators were related to the systems and genetics that underpin oyster productivity. The financial indicators of adaptive capacity are comparable to other states with the exception of the point that the costs of living in oyster growing areas are high and therefore affect availability of staff.

Collective actions in SA were often seen as necessarily driven by industry action. For example, improving the relationship between PIRSA Aquaculture and growers was regarded as something which required a proactive approach form the industry to ensure new government staff is inducted by the industry, so that growers could be sure that staff understood the fundamentals of the working of oyster enterprises. Comparably, a PIRSA staff member expressed the value of being in the field for the development of their knowledge and for providing opportunities to inform growers about government compliance and planning processes.

Table 5.13: Indicators of adaptive capacity for human capital from Streaky Bay and Port Lincoln workshops, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Human Capital (*the skills, health & education that contribute to the capacity to manage natural resources*)		
Availability of managers	Formal training on the management of oyster lease is absent for managers, owners and staff. There is a fair bit of unskilled labour. Bosses have to manage people and record goings on and management of stock and sales, etc. Diverse business structures with diverse employees. Managers proving to be a problem because it is a young industry. Human resources in low population area increasing concern.	Industry should link with schools to train people, and build interest in the industry, with identified career paths to management.
Availability of unskilled labour	Traineeship could follow earlier work experience and then management experience. Competition with other sectors -- especially mining.-- limits attraction of the industry to staff. Pay, conditions and work availability affect ability to find labour across sectors. Work ethic and ability allow people to move between industries. It is difficult to do succession planning with moving workforce.	Systems for training, maintaining and developing staff could be developed among growers and within the industry.
Acceptance of climate change	In SA there are less pressures and impacts associated with change. Population pressures on climate seems less ovious and therefore infeasible. Impacts aren't as great so people aren't as concerned.	Change needs to be visible and human impacts on climate system more convincing. Communication from science needs to clarify changes more clearly.
Succession planning	There is potential for industry to change as owner-operators retire. Children are not generally taking over, and this may lead current owners to change professions earlier (i.e. retrain to avoid the hard work of oyster farming in old age). There is some consolidation occurring within the industry. However, it is unlikely that this will lead to economies of scale reducing price of oysters as natural capital limits supply sufficiently to keep price stable.	None suggested

Table 5.14: Indicators of adaptive capacity for social capital from Streaky Bay and Port Lincoln workshops, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Social Capital (*the family & community support available, & networks through which ideas & opportunities are accessed*)		
Relationship between industry and PIRSA Aquaculture	There are problems of changing staff in PIRSA which can make interaction difficult. Consistency of relationships between growers and staff is important. Relationship at an industry level is also affected, as industry suffers frustration with mistakes and lack of knowledge about process. This can create feedbacks that make the problem worse (e.g. a frustrated grower abuses staff, staff quits, new staff know nothing..). Staff rarely have grounding in industry and operations or even marine background. Industry trying to become more professional in dealing with PIRSA. Perception that PIRSA is there to take money and not source of information or advocacy. Regulatory role is in the spotlight.	Industry need to effectively brief PIRSA staff. Industry can take a role in induction of new staff. Interchange between industry and PIRSA needs to occur through formal and informal channels. For instance, there is value in staff being in the field.
Relationship among state industry bodies	Increasingly strong and collaborative relationship between bodies. Deciding research priorities, identifying issues of common concern. Seafood CRC Oyster Consortium is key point of focus, and Aquaculture conference important time to get together. Shared research projects between states are developing.	Industry and growers can more effectively solve collective national issues through developing a broader network and encouraging network development at a national scale.
Relationships within the state network (SAOGA/SAORC)	Coherency of representative bodies is driving change through representation of growers. Industry has been working well in putting forward unified voice.	Disseminating information, establishing and maintaining credibility. Recruiting more growers could be indicator of success of this.
Community perception of industry	Puts potential pressure on industry which needs to be carefully managed. Government increased accountability for aquaculture. Identified need to develop strategy for escapes and large marine invertebrates: e.g. 'escaped oyster policy'. Losing face with community brought about projects but has also changed the ability to zone for oyster farms, where there is a reduction in public trust. The public will respond to zoning policies well if they view the industry well. Currently, the industry is generally well-placed in the community contributing economically and in other ways. Other sectors can affect perception of oyster industry.	Positive, proactive actions need to be taken in terms of industry engagement with the community. Information could be better extended to community. Industry can and will support such actions because they can see the value in them. Across aquaculture there are differences between cultures -- but these can be mediated and co-ordinated by peak bodies.

Table 5.15: Indicators of adaptive capacity for natural and physical capital from Streaky Bay and Port Lincoln workshops, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Natural Capital *(the productivity of land, water & biological resources from which rural livelihoods are derived)*		
Algal productivity	ChlA tends to have poor relationship with oyster productivity. Algal numbers are subject of conversation.	Real-time data from automatic counters could be implemented. These could be cost of SASQAP.
Access to productive leases	Some areas appear to be becoming more productive in terms of oyster growth.	Planning for zones into the future may require monitoring of algal productivity to detect trends, if any.
Physical Capital *(the infrastructure, equipment & breeding improvements to crops & livestock that contribute to rural livelihoods)*		
Availability of suitable land bases	Land base infrastructure is good in most places, but some areas have big problems: can make a big differences to operation if not close to launch facilities and facilities.	Continuous improvement through collaboration between industry and local government.
Suitability of growing systems	Development of suitable growing systems which are appropriate to conditions (e.g. increasing heights for sea-level rise). May need to move inter-tidal to subtidal if conditions change.	Continuous improvement (Industry/PIRSA endorsed systems) Lease arrangements shift to sub-tidal, and change between inter-subtidal lease infrastructure may be warranted and should be considered.
Handling systems	The single biggest input is labour. So efficiency depends on handling systems.	Continuous improvement (industry)
Genetics of stock	Warmer water oyster (one that is more adaptable to spikes in temp) may be needed in coming years or decades. Also resilience to acidification may become important over coming decades.	Current and ongoing industry investment in R&D

Table 5.16: Indicators of adaptive capacity for financial capital from Streaky Bay and Port Lincoln workshops, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Financial Capital (*the level & variability of the different sources of income, savings & credit available to support rural livelihoods*)		
Cost of SASQAP program	Cost of SASQAP (Food Safety) and PIRSA biosecurity is currently substantial. Increasing algal blooms and the need to look out for new species could increase cost of overall programs.	Efficiency of programs required to reduce costs.
Annual returns	State-wide economic indicator. Can not do returns on bay by bay basis because the data are not recorded. Too much movement at different life stages which increases the complexity of this variable.	
License and lease fees	Costs for access and operation of site based on cost recovery model, which affects bottom line.	PIRSA aquaculture/ industry continuous negotiation for operational efficiency
Ability to borrow against lease	Banks have been unwilling to use leases as collateral on loans. The security of tender and the first power of mortgagee (i.e. The bank) has been a problem. The history of sustainable growth in the industry has been demonstrated. The legal status of the lease is main impediment to borrowing against leases. This ha meant many people have ties business to mortgage of personal assets rather than business assets, in which case they can't deduct costs of borrowing. This constraint on borrowing as been a substantial handicap for industry.	Ongoing negotiation among PIRSA / industry and banks (which is well underway).
Location specific costs	Costs of living in oyster growing areas can be prohibitive and reduce labour availability. Commuting is expensive.	None suggested

5.4.3 Tasmania

The discussion of indicators of adaptive capacity in the Campbell Town workshop was similar to other workshops (Table 5.17 to 5.19), although the discussion was often more technical. For example, discussion of natural capital centred on the difficulty of distinguishing causal factors for changes in productivity because of the complexity of the drivers of oyster growth, health and survival, in both farming and hatchery conditions. In line with this technical approach, and in terms of human capital, growers emphasised that their collective and individual knowledge enhanced adaptive capacity and that knowledge networks and communication within industry and across research agencies was improving. Unlike other workshops, no indicator reflected that oyster aquaculture in TAS was affected by conservatism or other cultural impediments to adaptation; however the small-scale of many operations was seen as an impediment to achieving the economies of scale that might make businesses more resilient to shocks and the industry more attractive to staff. This scale issue was described as an artefact of socio-cultural and structural issues. For instance, the incentives for owner-operators are not usually created in the work arrangements of managers (e.g. managers usually work for a wage, rather than receiving remuneration on the basis of sales or profit). The indicators of social capital that were rated as most constraining were the *efficiency of process* and *whole of catchment management*. In relation to this indicator, growers described issues pertaining to planning and approvals processes for land based infrastructure and the time taken to upgrade utilities as a fundamental component of enterprise development. Some participants argued that statutory 10-year reviews for marine farming plans were too infrequent, despite provisions these plans on an as needs basis. Relatedly, and comparable to NSW, growers suggested that the diversity of government agencies whose decisions and action affect oyster aquaculture required that the industry and growers must engage with many different parts of government, both state and local to improve outcomes at the level of individual operations and industry. Physical capital indicators were not seen as particularly constraining and related to the hatchery operation and the availability of spat, and to the need to develop new infrastructure that is recyclable and made from recycled material. Selected indicators of natural and financial capital closely reflected other workshops.

The collective actions identified in the TAS workshop reflect a small maturing industry that is becoming increasingly technical, developing good representation and stronger interactions with government. Priority collective actions (for which actions were suggested) related mostly to social capital. Firstly, streamlining of process to avoid excessive duplication and transaction costs was seen as having potential to invigorate the industry by allowing more efficient and timely development However, the exact processes and duplications were not prioritised within the workshop. Secondly, inter-agency collaboration and co-operation for NRM at a whole of catchment scale was described as fundamental to the resilience and profitability of the industry.

Table 5.17: Indicators of adaptive capacity for human capital from Campbell Town workshop, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Human Capital *(the skills, health & education that contribute to the capacity to manage natural resources)*		
Enterprise structure	Orientation of family business: creates ceiling for non family employees. As industry matures there will be increasing opportunity to build broader business models. Corporates who own multiple leases suffer from low productivity because employed managers tend not to have same level of responsibility and incentive for proactive management .	Growers and industry could investigate diverse models for medium scale businesses to incentivise proactive management for employees. These could be made concrete through case studies of different business management models.
Knowledge of owner operators	There are a relatively large number of people in the industry with good knowledge of the oyster aquaculture and strong business skills.	None suggested
Availability of training	Certification requirement, management experience and training not available. Can get training through TAFE -- but this needs to be better tailored to needs of growers.	Increasing need to develop more targetted training projects as industry becomes more technical.
Industry attraction to staff	Oyster aquaculture is not seen as career path. Rather, it is viewed as a low skilled job. But it increasingly needs more brains than unskilled labour. It is hard to retain people in area, partly because of net outflow of population regional areas .	None suggested

Table 5.18: Indicators of adaptive capacity for social capital from Campbell Town workshop, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Social Capital *(the family & community support available, & networks through which ideas & opportunities are accessed)*		
Efficiency of process	Current political and bureaucratic situation impedes change and therefore responsiveness of industry and adaptation. Applications to Council take a very long time, and State and Local Government decision-making is often very slow. When relationships with people in agencies are good, action can be faster. Many different organisations and agencies to work with make development complicated and difficult. If the issue are life and death things happen quickly, otherwise things often happen very slowly (i.e. DPIPWE can react on short timescales, but tends not to). Ten year plan review is slow and constraining. Also, political intervention can hamstring action. Agencies may not realise the amount of work and expense of compliance. Leniency exists in system, but may need to be formalised as growers appear to have different experience.	Streamlining bureaucratic process is very important. Statutory processes very difficult to change. Opportunities for substantial industry growth could be better facilitated by stronger partnerships between government agencies and industry.
Flow of information	Information is crucial, and flows are improving. Oysters Tas has helped with sharing of information among growers, and key organisations and bodies TORC, TSIC, TAC.	Ongoing improvement in co-ordination between organisations and agencies
Relationships with state government agencies	Various tensions exist between industry and growers with different government agencies, lack of understanding of issues and responsiveness to industry/grower needs are widely perceived.	Measures to improve relations will increase understanding across boundary, encouraging responsive and proactive behaviour, and mutual respect.
Industry representation	Starting to engage with public to build policy and public legitimacy. Established industry has more clout. For instance, people accept that landowners own land, this social license affects ability of an industry to self-organise. Social license to operate needs to be more formalised for better organisation and representation at state and national level.	A single (unified) body could be developed for industry that will allow better organisation and representation.
Whole of catchment management	Whole of catchment management is important to ensure industry is not too greatly affected by upstream management. Point source pollution and competing interests can have substantial impacts.	Inter-agency co-operation and collaboration is important, as is cooperation between state and local governments and NRM groups, who should play a key role.

Table 5.19: Indicators of adaptive capacity for natural, physical and financial capital from Campbell Town workshop, including key pressures and collective action priorities.

Indicator	Key pressures	Collective action priorities
Natural Capital *(the productivity of land, water & biological resources from which rural livelihoods are derived)*		
Environmental flows	Quality and quantity of environmental flows are both variable and can affect productivity.	None suggested
Access to foreshore	Taking up land bases as sea level rises and/or erosion affects current land bases.	Crown land availability and access may need to be better defined if sea-level rises.
Size and position of farms	Growers need enough space to grow stock and some areas are limited in the ability to produce stock.	None suggested
Phytoplankton or Chlorophyll-a	Measure of biological productivity which also provides an idea of potential carrying capacity	Improve monitoring of productivity/food (Industry/Government in partnership)
Physical Capital *(the infrastructure, equipment & breeding improvements to crops & livestock that contribute to rural livelihoods)*		
Spat availability	Maintaining supply of spat is essential for production and there are few hatcheries on which many growers depend. This makes hatcheries a potentially weak link, but their management is well organised to ensure consistent outputs.	There is a commercial imperative to have few, relatively large scale hatcheries.
Appropriateness of infrastructure	May need to re-engineer plastics and allow recycling of used infrastructure.	Industry could investigate recycling options (inputs and outputs)
Financial Capital *(the level & variability of the different sources of income, savings & credit available to support rural livelihoods)*		
Security of tenure	Leases are only for 30 years and therefore hard to borrow against. This has affected industry development.	Industry, Government and banks can work together to improve the ability of growers to borrow against leases.
Costs of fixed infrastructure	May become more expensive and less valuable over time, posing a potential risk for investment.	None suggested
Value of foreshore land	There is uncertainty around the future value of foreshore land. It may decrease as sea level rises or may become increasingly in demand, in which case it could limit access for land-bases.	None suggested
Cost recovery arrangements	TASQAP cost recovery arrangements affect bottom line to some degree and these costs may increase.	None suggested
Closure costs	Frequency of closures may increase if there are increasing frequency of high rainfall events. These impose costs on growers, which may affect bottom line.	None suggested

5.5 Adaptive capacity – cross scale issues

Indicators of adaptive capacity demonstrate substantial similarities across oyster growing areas. In summary form, these similarities are evident in recurrent indicators of adaptive capacity across workshops (Table 1.2, Section 1.5). Such recurrence of issues that both constrain and enable adaptive capacity implies that there is substantial potential for the oyster industry to work across state boundaries to develop adaptive capacity as a single sector, improve industry wide outcomes and reduce duplication of effort.

Indicators of human capital ranged from concerns about apathy, conservatism and individualism among growers in NSW, to the limited capacity to adequately train and maintain staff, which was ubiquitous. Time constraints and ability to develop and expand businesses were linked to external, structural constraints, and were thus often considered difficult to change or work around. For instance, time commitments required to undertake compliance activities under diverse regulatory structures were seen as an increasing burden on labour. Expanding an enterprise was frequently described as being predicated by a widespread inability to borrow against lease entitlements. Some growers presented these issues as limiting development of human capital. By and large, there was an expression that leadership in the industry, though comprised of an overworked minority, was active and reasonably effective.

Constraints for both human and financial capital were often described across workshops in terms of closely related issues of enterprise development and succession planning. Family run operations, while the norm, were seen as having limited ability to expand for a variety of reasons. In all workshops the ability to borrow against leases was described as a crucial constraint that is currently being addressed. Another issue relating to expansion was the difficulties of finding managers with appropriate skills. Yet there was also concern that oysters are best looked after by owner operators as managers on a wages have less interest in ensuring good rates of growth and survival where the work required for these outcomes can be arduous and inconvenient.

Indicators of social capital reflected the wide variety of relationships that are integral to adaptive capacity – those with community, local and state governments, and within and across industry. Planning and compliance were widely described as increasingly complicated and time-consuming. Across all states some compliance requirements were seen as impractical or impossible by oyster growers, and in some cases were presented as examples of governments' lack of understanding of the realities of oyster farming. Although, SA growers aired such grievances about relationships and processes with government, these were directed to a single agency – PIRSA Aquaculture. Growers in other states were concerned that the multiple agencies and bureaucratic processes that they needed to engage with were poorly streamlined. Some participants suggested that perceived inefficiency could be remedied through coordination of governance through a 'one-stop-shop'. Some also suggested that institutional attitudes to oyster farming did not reflect either the environmental importance of the sector or its economic importance to regional economies.

Another recurrent theme under the rubric of social capital is what growers from the Campbell Town (TAS) workshop referred to as a 'social license to operate'. In NSW, OISAS provides a clear policy formulation of this license by prioritising oyster aquaculture as the preferred outcome in specific areas and legislating consideration of this in upstream and downstream management. Some participants from both NSW and TAS reflected that, despite such policy provisions, various tiers of government still sometimes prioritise upstream interests over the oyster industry. Variously, participants suggested that governments allowed developers, water authorities, forestry operations, graziers and others to derogate their responsibilities to ensure that waterways were not contaminated. In TAS and southern NSW these issues were considered to be at least somewhat ameliorated by organisation within the industry and partnerships with regional NRM authorities work was described as building linkages between aquaculture and terrestrial farmers and encouraging whole of catchment perspective and management.

Participants in TAS and especially NSW workshops were concerned about many aspects of upstream management: riparian zones, water resources, point source pollution, agricultural chemicals, acid sulfate soils, forestry operations and land clearing all have potential impacts on oyster aquaculture. Some climate change projections indicate increasing intensity and duration of droughts along with fewer but more intense downpours (Hennessy et al., 2007). Such conditions would exacerbate both low nutrient estuarine conditions experienced in dry times and the potential for toxicity in wet periods. In this context, co-ordinated management of catchments is vital and something requiring continued attention. In southern NSW, the regional NRM authority was described as actively and effectively engaging with this management through community endorsed Catchment Action Plans. Yet, in parts of this region, growers were concerned, often palpably angry, about the ability of upstream interests to change water entitlements and land use and thereby impact on downstream oyster aquaculture without recompense. These issues, ostensibly about governance, were often described by growers as requiring improved scientific knowledge to understand the biophysical causes of oyster growth and mortality and thereby the thresholds for impacts in relation to their potential upstream causes. Oyster growers in both estuaries and bays made a strong case for development of monitoring schemes which serve both public and private interests – monitoring estuarine and coastal health and productivity, and developing a better baseline understanding of these in the context of regional environmental conditions, natural resource management evaluation, and environmental change. The prospect of changing rainfall conditions and increasing population pressure in catchments and on water resources were described by some participants as creating a greater imperative for improving baseline understanding of oyster growing environments as well as continual improvement of upstream management.

The integration and improvement of monitoring programs for bays and estuaries was also reflected in ubiquitous indicators of natural capital that related to the primary productivity of bays and estuaries. Current monitoring was variously described by both growers and scientists as poorly co-ordinated, piecemeal, not effectively contributing to advances in either scientific understanding of processes and sensitivities, or to assisting with management of oyster aquaculture. Even basic data about variability in salinity, temperature and pH are patchy, spatially and temporally. Many growers have their own monitoring programs in place, and some of the larger operators have systematic scientific programs including phytoplankton floristics and productivity. For most growers, however, the biophysical system on which their livelihoods depend remains poorly understood. Growers across the regions expressed an enthusiasm and willingness to develop such understanding through involvement in monitoring in partnership with government and research facilities. Growers, researchers and staff of NRM bodies advocated that such a system, if well integrated and managed could result in multiple public and private goods, including: increased scientific understanding of estuarine processes, improved understanding of environmental precursors to disease outbreaks, skill and knowledge development and improved adaptive capacity to among growers. Such a program could also enable productive exchange between researchers and resource managers, including oyster growers.

Physical capital indicators consistently related to the development and availability of appropriate infrastructure and stock, and having sufficient access to foreshore and land bases. The consideration of breeding improved oysters to deal with changing environmental conditions was also a relatively consistent theme. Although genetics were considered important across workshops, in southern NSW where Winter Mortality presented a current and substantial threat to the industry, the development of disease resistant breeding lines was regarded as the central priority for research. Other physical capital issues were rarely expressed with such urgency across workshops. Rather they appeared to be evolutionary and largely well covered by an industry that, in recent decades, has reached a stage of maturity, in which investment in development of infrastructure is consistent.

The current scale and structure of oyster aquaculture enterprises does not necessarily enable fast and flexible responses to unprecedented events. Most workshop groups indicated that there is little flexibility to deal with events such as floods and harmful algal blooms. Moving stock is too difficult and costly to allow for any substantial uptake of emergency lease provisions. Where stock is threatened by local conditions most growers are probably unable to move them to other leases over which they hold tenure, or to agist on other leases.

Across all states, the ability to develop enterprises that would be large enough to be well buffered against shocks (originating either in markets or from substantial stock losses) was often described in terms of profit and ability to borrow against leases. Profit is driven by diverse issues, not least of which being the returns from farm-gate sales of product. These are substantially lower than wholesale prices. As one grower in southern NSW put it, “there are too many people between us and consumers”. This statement prompted discussion of attempts to form co-operatives among growers, and commonly, of the failure of such endeavours. The widespread and historic inability to borrow against an oyster lease was discussed as something at the cusp of change, with some growers indicating that they had recently secured loans independently (in TAS) or through joint initiatives between industry, state government agencies, and banks (in SA). Other issues commonly raised were the costs of doing business, relating to overheads, infrastructure, compliance costs and license fees and the cost recovery associated largely with quality assurance programs.

6 Discussion of vulnerability and adaptive capacity: threats and opportunities

The approach applied to RCVA in this report is a novel and effective means of understanding the key issues that contribute to the vulnerability of the oyster industry to climate change. It also helped to identify the factors that constrain and enable adaptation within oyster aquaculture. The preceding presentation of workshop results identified perceptions of vulnerability across the oyster industry in Australia. This provides a useful starting point for assessing what can be done to avoid or delimit potential climate change impacts. The purpose of this report is not to refute or counter the perceptions of key issues offered in the workshops but to highlight these current priorities for the sector as points of departure for future and ongoing work. Many of these issues reflect a desire among growers to understand better the functional ecology of oyster growing environments and variability in these systems, and what these issues mean about the bases of oyster productivity and health. Some growers discussed scientific research and monitoring and how their understanding of systems had been advanced through their engagement with such science. Yet, for many, probably most growers, there remain substantial knowledge gaps which are perceived as presenting uncertainty for the oyster industry into the future. The argument of growers regarding the management of such uncertainty in relation to climate change can be summarised as follows:

Oyster growers derive livelihoods from the availability of a public good – clean bays, estuaries and coastal lakes. The industry depends on these conditions, and it serves a public good through defending them in its own interests. In the absence of oyster farming (and other bivalve production), the provision of water quality in estuaries would be a public good that governments would need to ensure solely via their own programs. Climate change impacts may come from a variety of exposures. Climate change is projected to affect the pressures on oyster growing areas variously via changing water temperature, phenology, rainfall and run-off, sea-level, storm surge frequency, acidification and potentially other factors. These changes remain difficult to project. Some will be positive, some negative, but most remain uncertain. This is especially the case in the context of understanding of the environmental pre-cursors of diseases. Yet disease conditions can destroy the oyster industry locally. Uncertainty around such high consequence impacts requires a precautionary approach, and one which enables learning about the pre-cursors of disease and the ecological condition of estuaries. Reduction (or maintenance of low levels) of non-climate stressors should form a central aspect of this approach.

This line of thinking corresponds with the precautionary approach under the National Framework for ESD (Commonwealth of Australia, 1992) to which all state legislation governing oyster aquaculture adheres. The principle implies that oyster aquaculture should not be expected to provide the burden of proof that upstream impacts have deleterious effects on production. In the context of estuarine systems in NSW and TAS, the imperative to manage non-climatic stressors implies continuous improvement in NRM, or maintenance of high quality NRM, and effective, well-prioritised, and clearly articulated management of upstream resources (e.g. pollutions sources, environmental flows, etc..). Where trade-offs are deemed necessary these should be as transparent as possible. However, the effectiveness of an approach to managing climate impacts via improved management of non-climate stressors will rely of detection of the effects of resource management decision on stressors via monitoring and research, into estuarine water quality and the pre-cursors of its variability. That is, it relies on being able to attribute oyster stress to environmental stressors. Such attribution may be scientifically difficult or impossible because of the complexity of estuarine systems (Mount, 2008).

The sustainable management of estuaries, bays and tidal inlets as public goods in the context of a changing climate require considerable coordination across government and industry organisations, through formal and informal institutions and relationships. This will require effective and integrated development and application of knowledge for decision-making across scales, and for both practice and policy. Such institutional arrangements already exist to some degree, though they are variable across the three states and within them and the complexity of these arrangements makes precise mapping of their strengths and weaknesses beyond the scope of this report.

The oyster industry is well positioned to take advantage of many of the imperatives and opportunities of adapting to climate change. It has substantial opportunities to partner with local and regional organisations and communities to ensure that estuarine water quality is maintained in the face of potential changes to the ecological function of these systems. Adaptive capacity can be generated through such linkages in ways that are often difficult to predict. For example, industry and local growers could partner with regional universities or local schools to undertake long term monitoring of ecological health and this work can contribute both analytical knowledge and changing societal perceptions and ecological literacy that improves community perceptions of oyster aquaculture, and reinforces its social license to operate. The indicators of adaptive capacity that were described in workshops reflect a growing literature on adaptive management and governance that embraces system complexity and uncertainty through multi-level co-management (Armitage et al, 2007). The evolution of co-management arrangements that are adaptive will require commitment and resourcing from both governments and industry bodies.

As well as dealing with uncertain futures, there are some specific impacts around which there is greater confidence. (As discussed in Section 7.3.3, these relatively likely impacts should be dealt with through specific risk management measures). They relate to increasing water temperature, longer duration of high water temperature, higher frequency heatwaves, changing distribution of algal species including HABs and increasing acidification of water. There is less confidence around other potential impacts. Nevertheless, these may be more consequential than the changes previously mentioned.

Synthesising the potential impacts of climate change and self-assessed adaptive capacity within the oyster industry, across NSW, SA and TAS, reveals a great deal about the vulnerability and resilience of the industry across these states. It is apparent from this first-pass assessment that the positive and negative consequences are likely to arise from climate change and these will be unevenly distributed, temporally and spatially. There are substantial uncertainties associated with regional climate impacts and they need to be considered in the broader context of societal changes and associated shifts in land and resource use. These uncertainties associated with broad system complexity and the feedbacks between the sub-components of vulnerability make a definitive assessment of vulnerability impossible (Turner et al, 2003). Nevertheless, relative vulnerability can be inferred through the detail of workshop discussions in the context of scientific assessment of climate risk. From this synthesis, at a state level, it would appear that the NSW industry in general is potentially more vulnerable to the impacts of climate change than TAS and SA.

Higher vulnerability in NSW results from a variety of factors. SROs are potentially more sensitive to projected climate change impacts than POs, largely because of disease vectors which may become more prevalent under climate change projections. Greater population pressure in NSW resulting from tree-change and sea-change development may lead to exacerbation of current issues in some areas, which could be worsened through gradual climate changes. Conditions which lead to oyster stress or harvest closure may become more frequent if high intensity rainfall increases, for example. These issues, along with a substantially more conservative, distributed, and less engaged population of growers make the NSW industry potentially vulnerable to climate impacts.

The east coast of TAS is likely to be susceptible to occasional, but increasingly frequent events in which high summer rainfall and warm ocean temperatures result in short-lived conditions which may adversely affect oyster growth or survival. There is also increasing likelihood of changing distribution of harmful and other algae affecting this region. However, in both southern NSW and TAS oyster growth may increase concomitantly with water temperature. Anecdotal evidence suggests that the opposite trend might occur in northern NSW.

Changing conditions in SA are probably the least understood. Variability in water temperature and nutrient availability are high and dependent on complex and poorly understood processes. These and other uncertainties make specific impacts on oyster aquaculture very difficult to predict for this region. Nevertheless, changes in oceanic processes could have substantial impacts across side geographical areas if unprecedented upwelling events (or the absence of upwelling over extended periods) occurred. These scenarios are worth considering both by industry and growers. The SA industry is also well placed to work strategically to address longer-term changes such as acidification, through breeding programs. Moreover, the SA oyster industry, government and research bodies are in a good position to develop adaptive co-management arrangements which could enable greater institutional flexibility and thereby increase adaptive capacity in the face of many of global change, broadly speaking.

7 Recommendations

The first pass assessment of vulnerability conducted in this project indicates that there are specific actions that could increase the resilience and adaptive capacity of oyster aquaculture. There are also opportunities for specific reductions of sensitivity within local and regional oyster aquaculture. These actions variously require leadership from industry at local and regional levels, and evolution of structures, institutions and management practices across government and industry. In this section we outline recommendations that are common across jurisdictions, before detailing state specific recommendations. It is important to emphasise that these recommendations do not negate the work that government agencies, industry organisations or individual farmers have done thus far on specific or generic matters. Rather, they highlight processes that may be incipient or in progress but have been identified through the RCVA approach to require continuing development or attention. Across all state government agencies there is strong commitment to continual improvement, yet many of the issues raised in workshops and elsewhere suggest a means of developing improved or more transparent processes in order to foster more adaptive and sustainable oyster aquaculture. While these recommendations have not been prioritised specifically, they can be considered as priorities in relation to the degree to which particular issues are constraining or enabling. Much of the work of prioritisation will need to be done through state-based dialogue in committees and between industry and government. Recommendations relevant across state jurisdictions are detailed in the following categories: collective action, governments; industry bodies; growers; and research agencies. State specific recommendations are provided at the end of this section.

7.1 Recommendations for collective actions across jurisdictions

Discussions across all the workshops point to a series of comparable actions that will enhance adaptive capacity in all states. Each state will have different priorities and need to interlink any actions with currently existing, or proposed, legislation, management frameworks and programs. Thus, the following recommendations are indicative of state-based action. In each case the collective actions have substantial possibility of collaboration across government agencies, industry and research agencies.

7.1.1 Investigate the improvement and integration of estuarine and coastal monitoring system across oyster growing areas

A fundamental constraint for adaptation across all states and workshops was limited knowledge of baseline conditions, variability and dynamics of coastal and especially estuarine systems. Workshop participants commonly described current monitoring of bays and estuaries as poorly integrated, and existing short-term studies of particular localities and estuaries as having limited ability to provide a baseline for monitoring climate change impacts, unless these are linked to continuous data sets or models. Monitoring, in this context, would underpin analysis for management and decision-making both within public and private spheres.

In all workshops oyster growers were keen to improve their understanding of baseline conditions, variability, trends in water chemistry, linkages between phytoplankton abundance and types and oyster productivity. In NSW and TAS, the associations between estuarine conditions and rainfall in catchments were also often described by participants as fundamental to understanding the system. The cost of such comprehensive data collection is likely to be prohibitive, in part because of the complexity of processes in bays and estuaries and their uniqueness. Nevertheless, developing risk management and improving estuarine management is likely to require some improvement in current monitoring of estuaries, and general estuarine monitoring may provide insights into the pre-cursors of oyster health, mortality and growth. To this end there may be capacity to synthesise existing datasets, and augment them, especially as automated monitoring systems become more cost-effective and reliable.

There are clear grounds for developing improved systems of monitoring estuarine conditions in order to understand baseline conditions, detect changes and understand sensitivities (for instance, the environmental precursors of disease and ecological change), and evaluate upstream NRM initiatives. Hobday et al (2006: 30) stressed the general need for such monitoring across marine environments:

> In principle, an immediate policy strategy for adapting to climate change impacts on marine ecosystems will include fishery and pollution management systems that are adaptive to climate change impacts. However, without quality monitoring and modelling programs, such integrated management strategies are not likely to be effective, nor would the effectiveness of any such adaptation efforts be measurable.

In estuarine systems substantial work and interest exists in improving monitoring and analyses. Development of a co-ordinated and integrated approach to monitoring estuarine and coastal water quality conditions has been the subject of ongoing investigation and initiative (see Mount, 2008). Concerns about oyster health (as a result of high rates of mortality, for instance) should be considered as indicators of biophysical change, and be a trigger for monitoring and research in specific areas, especially where oyster aquaculture is a substantial contributor to the regional economy. At best, monitoring and analysis should aim to effect social and policy learning through building linkages between scientists, oyster farmers, NRM bodies, Local Councils, and State Government Agencies.

There is a persuasive argument for improved monitoring of specific biophysical parameters in bays and estuaries using public monies (see Section 6). Beyond private benefits for oyster aquaculture, improved and integrated monitoring systems could provide substantial benefits in providing baseline conditions against which climate impacts can be monitored, NRM initiatives evaluated, and the environmental quality of important ecosystems benchmarked. In the view of some participants, accountability for upstream activities that have impacts on oyster aquaculture can rarely be attributed to specific causes because to a lack of general monitoring. If this is the case, externalities of upstream activity cannot be effectively valued where monitoring is insufficient to determine their impacts. However, the complexity of many systems means that such causality will often be hard to establish through even the most sophisticated monitoring or modelling programs.

The development of any integrated monitoring program would require specific expertise, consultation, coordination and the development of appropriate institutions. The findings of this report indicate that any development of integrative water quality monitoring should consider a variety of specific issues, including:

- Investigation of existing monitoring schemes: these vary widely across states and are conducted by a variety of government agencies, tiers of government, research organisations, individuals and non-government organisations. They have varied objectives yet there are potential synergies as well as overlaps between them.
- The development of pilot schemes: these should be done in areas with the greatest potential vulnerability. For example, they should be prioritised in areas where unexplained or disease-related oyster mortality has been high, and especially where these areas are prioritised as oyster growing areas. In particular, this report found that vulnerability to climate impacts is potentially greatest in NSW.
- Monitoring requires common methods in order to generate comparable data across environments.
- Automated equipment: recent developments in equipment for scientific monitoring programs such as equipment used in the Integrated Marine Observing System (IMOS) could allow for efficient and easily collated digital datasets, especially for key physical and chemical variables (temperature, salinity, pH). This equipment would require ongoing maintenance and calibration.
- Integration with offshore monitoring such as IMOS, in order to establish linkages between shelf process and the conditions in bay and estuaries. Such integrated monitoring could provide early warning of specific conditions that might need to be managed by oyster farmers.
- Utilisation of central repository and ensuring free public access: Moves towards ensuring central repositories and public access of publicly funded monitoring programs have been established for terrestrial (Bureau of Meteorology) and oceanic monitoring (IMOS) programs, and any integrated

program for monitoring estuarine water should learn from these models to encourage analysis of the data.

- Linkages with existing benchmarking and EMS programs: Many growers raised the usefulness of existing and developing programs (e.g. the Seafood CRC Benchmarking program, and the Environmental Management Systems in NSW) and said that these could be taken further with the inclusion of environmental data.
- Potential for efficiencies to be gained through citizen-science programs. Close collaboration with the oyster industry and other aquaculture sectors could provide efficiencies in the collection of some data. As one grower put it, "oyster farmers are exquisitely placed to collect data" because much of the data is both in their interest (although conflicts of interest need to be considered closely) and they are already on the water. Quality control and verification of some forms of monitoring would need to be thoroughly investigated to enable these efficiencies.
- There is good potential to develop strong linkages with existing NRM programs such as the Ocean watch 'tide to table' program (http://www.oceanwatch.org.au/our-work/tide-to-table/).

7.1.2 Develop preparedness for changing conditions and extreme events

The oyster industry and individual enterprises need some support to undertake their own analysis of their vulnerability and understand what adaptive strategies and forms of adaptive capacity are likely to enable them to reduce the negative consequences of climate change and capitalise on the benefits of change. This can be assisted through thinking through responses to plausible scenarios at a business level or in regional group settings.

Shellfish quality assurance programs run by each state need to be aware that previously undetected algal species may appear and bloom and some of these may be harmful to human health. Such range extensions may be monitored or predicted by research organisations and formal networks and linkages between these organisations and with quality assurance programs could be effectively facilitated via the Australian Shellfish Quality Assurance Program.

7.1.3 Develop flexible structures and institutions that can contend with emerging issues and unforeseen events

The ability to deal with unforeseen events requires effective formal structures and institutions in place to deal with emerging issues. These issues may result from one-off events or step-like changes which will often need to be addressed through efficient, whole-of-government approaches, which integrate local and scientific knowledge. Assessment of the flexibility of structures and institutions in the event of unforeseen changes will be hard to assess except following events themselves. Yet indicators of such arrangements are likely to be strengthened by ongoing strengthening of networks of governance and trust through, for instance, effective, well co-ordinated advisory committees comprised of geographically distributed representatives of oyster growers, government staff and scientific experts. In the context of building adaptive capacity and resilience, such committees could actively engage with scenario planning processes to increase their capacity to deal with unprecedented conditions.

7.1.4 Continued work to ensure lease entitlements can be used as equity

The ability to use leases as equity in order to borrow and expand businesses was seen as an impediment to growth and development of oyster aquaculture operations across workshops. In some areas, recent initiatives had overcome this issue to some degree, but more work needs to be done by industry, banks and state governments to find ways of facilitate borrowing against leases. There is good potential for learning across state jurisdictions to develop this initiative further. For example, PIRSA Aquaculture has shown some initiative in developing documentation to clarify for banks the status of lease entitlements under the SA *Aquaculture Act* (2001), and where possible to strengthen the security of these entitlements.

7.1.5 Enhancing adaptive capacity through collaborative industry-government training programs

Enhancing adaptive capacity will require collaboration within the oyster industry, across industries and between industry and government agencies. In many workshops there was a sense that staff of government agencies do not understand the practicalities of oyster farming and how these constrain what can be done and within what timeframes. Conversely, among staff of government agencies there was some frustration that oyster growers did not appreciate the processes in place and their rationale. In short, between government agencies and growers, there are apparent gulfs in knowledge and understanding that could be remedied via improved communication. Specifically:

- industry bodies should consider developing induction manuals for incoming government agency staff;
- government agencies should make their processes and their rationale as transparent as possible via the publication of these as practical guides;
- government agencies should consider regional organisations or individuals that are well-networked within the oyster industry and utilise these networks for extending communication where possible;
- traditional factsheets and web-based communications currently lack the reach and depth of face-to-face communication and, while the latter is expensive, if well-targeted the ability of government staff to visit leases of key growers (i.e. opinion leaders) is likely to increase the levels of understanding across boundaries and foster improved relationships, communication and trust between growers and government agencies.

7.2 Recommendations relevant to state and local governments and regional NRM authorities

7.2.1 Continuous improvement of coordination across government agencies to maintain and improve estuarine water quality in the face of climate change and variability

Whole-of-government approaches can reduce the risks of oyster aquaculture zones being adversely affected by upstream land and water management and pollutions sources. These approaches require careful specification of roles and responsibilities, and specific measures for ensuring accountability and transparency, and thus to ensure that distributed responsibility does not become a dereliction of duty. They can also be developed through introduction of processes which explicitly address values and power relations in strategic planning and decision-making for land-based activities via the use of methods and tools which incorporate these aspects of decision-making in a constructive and transparent manner (e.g. multi-criteria decision analysis; well-facilitated, outcomes-focussed meetings), or through the development and promotion of boundary organisations, which are accountable to industry, government and the broader community (see Guston, 2001). Regional NRM bodies may be able to serve this sort of role for oyster aquaculture in NSW and TAS, but would need to be sufficiently resourced for such work.

7.2.2 Ongoing improvement in streamlining of process, compliance and bureaucratic efficiency

Participants across workshops were keen to increase the efficiencies associated with compliance and planning for oyster aquaculture, and therefore reduce the transaction costs associated with development. These costs were often described as inhibiting enterprise growth or diversification, and thereby making enterprises less resilient in the face of change than they possibly could be. The *Best Practice Framework for Regulatory Arrangement for Aquaculture in Australia* (Primary Industries Ministerial Council, 2005) undertakes annual appraisals of the state government policy processes and frameworks with a view to encouraging such efficiencies. The *Best Practice Framework* emphasises a move towards a single entry point for applications and project management through this interface between government and growers. The establishment of a single entry point for planning assessments and compliance is likely to improve efficiencies and reduce duplication of effort across government and oyster growers. It can also create better mutual understanding across the spheres of government and industry if staff with an intermediary role can be inducted by the industry as well as various government agencies and thus be able to effectively represent and mediate between different elements of the management and governance system. Workshop and other discussions, however, indicate that a component of the frustration from both oyster growers and staff of relevant government agencies stem from lack of understanding of the constraints across boundaries. For instance, a common concern for oyster growers was that government employees lack an understanding of what is possible for growers and the relative importance of different issues. Meanwhile staff of government agencies mentioned that thorough, transparent assessment under specific legislation and policy provision inevitably involve several steps, often across different government agencies, and therefore take time.

7.2.3 Planning for infrastructure replacement and upgrade: local councils, supported by state government agencies

State government and local councils, especially in NSW and TAS, need to plan for the effects of sea-level rise and storm surge events. Much work has already commenced in this regard. For oyster aquaculture priority concerns relate to strategic replacement or upgrade of low-lying sewerage treatment systems and septic systems, and planning for the relocation of the land-bases out of which oyster aquaculture operates.

7.3 Recommendations to industry bodies

7.3.1 Develop a national co-ordinating organisation made up of representatives of state based industry organisation

Formalised coordination across state industry bodies could serve to co-ordinate representation of the industry across jurisdictional boundaries, enabling improved linkages, synergies, and reduced duplication of effort. Such coordination is currently undertaken for research through the Oyster Consortium of the Seafood CRC. Formalised efforts to, for example, develop and build on the Industry's social license to operate through community engagement and representation to government, could be more efficiently achieved via a national program.

7.3.2 Contribute to a culture of responsibility and engagement within industry

Cultural issues within industry that were raised in workshops, especially in NSW, are difficult to change, yet steps can be taken to build leadership capacity and succession. The effectiveness of leadership across the industry is crucial for the adaptive capacity of the industry as a whole as it allows the industry to secure and mobilise knowledge and resources, to engage more effectively with policy, politics and science, and to represent itself effectively. The industry can improve leadership programs, promote proactive engagement with government and community, and devise appropriate rewards (e.g. travel bursaries) to encourage greater engagement of younger growers with the industry. Industry groups also need to encourage some active individuals to mentor potential leaders and will often need to reduce other voluntary workload of these individuals to do this mentoring. As the basis of the industry becomes more technical it may be useful to have mentoring programs that focus variously on scientific, policy and political/media engagement.

7.3.3 Develop risk management approaches within industry

In collaboration with individual growers and regional grower groups, peak industry bodies have a key role in identifying 'best practice' and 'best fit' strategies for sustainability and growth. These strategies and practices are likely to increasingly need to consider how they can accommodate climate change impacts such as changes in sea-level, wind and storm surge exposure, high river flow (fresh) events. Best practice projects and programs need to include risk management for ongoing change and infrequent, high consequence events.

7.3.4 Encourage growers to work together to identify regionally appropriate approaches to risk management

For example, and where possible, risk may be spread by growing different animals or different breeding lines, by moving, selling or agisting stock in the early stages of harmful algal blooms or by operating across different bays or estuaries. Risk management initiatives need to be considered carefully for specific regions and localities. These will continue to be subject to experimentation among growers. Industry bodies play a pivotal role in formalising local knowledge through providing opportunities for social learning, networking and challenging pre-conceptions.

7.4 Recommendations relevant to growers

7.4.1 Develop and review risk management strategies

Key risks associated with climate change relate to exposure to the specific biophysical changes. The impacts associated with these changes cannot be predicted precisely, yet there is reasonable confidence that some degree of change is likely. Risk management approaches to deal with these changes can take various forms. For instance (Hallegatte, 2009, pp. 240-7) suggest six broad approaches to managing for uncertain risk by adopting approaches that are cost-efficient. These will often be able to be pursued by growers individually or in groups through their own research and knowledge of local conditions and changes:

- ❖ No-regrets: do things that will be of benefit without climate change (e.g. invest in oyster breeding for multiple desirable traits, improve management of water quality).
- ❖ Win-win: increasing energy efficiency where possible reduces costs and emissions
- ❖ Reversibility / flexibility: minimise costs of being wrong by leaving options open (e.g. rent or lease expensive equipment that is only useful in extreme conditions?).
- ❖ Safety margins strategies: it is often cheaper to build infrastructure to cope with pessimistic scenarios than to retrofit or rebuild later (e.g. heavier duty lease infrastructure may be a worthwhile investment in areas where increasing wind, storm surge or floods are projected outcome).
- ❖ 'Soft' strategies: social, institutional and planning changes (e.g. developing linkages with other growers, scientists and government agencies can improve knowledge and ability to deal with situations as they emerge).
- ❖ Reduce decision horizon: long term investments may become increasingly risky. Inexpensive infrastructure with shorter life-spans may be more appropriate in areas that are already marginal.
- ❖ Synergies with mitigation: ensuring that strategies do not compound the overall problem or create greater dependence on energy intensive processes (e.g. developing markets which are reliant on air transport).

Specific approaches to managing risk for oyster growers might include:

- ❖ Consider enterprise expansion into different areas, species or breeding lines. These option spread risk geographically and through diversification);
- ❖ Spread financial risk or diversify livelihood strategies through off-farm investments or work.
- ❖ Management of specific climate change impacts could include:

- ❖ Heat waves: For SROs it may be useful to develop approaches to avoid overheating of beds at low tide (spraying, shading, reflecting light); For POs, times when oysters can be handled may need to be adjusted according to frequency and intensity of heatwaves in SA.
- ❖ Changing sea-surface temperatures: adjust times of year for particular activities and expect changed timing of events (growth windows, spawning).
- ❖ Sea-level rise: some growers have already lifted rack heights and achieved lower rates of mud worm infestation and other problems. Growers should be mindful of changing sea-level when replacing fixed infrastructure, and consider whether the flexibility of long-line systems may provide cost benefits where infrastructure is replaced infrequently.
- ❖ The use of ENSO forecasts to develop risk profile for seasonal rainfall and stream-flow conditions for estuaries should be considered, especially in NSW and NE TAS.

7.4.2 Develop preparedness through scenario planning

By thinking through current local variability in conditions and the plausible scenarios in terms of management, options for dealing with plausible events can be developed by growers, regional groups and industry bodies. Growers in NSW and TAS, for example might consider a scenario in which a large bushfire in a catchment is followed by a flood. What could be done to deal with the ensuing conditions? For example, can oysters be moved, agisted, sold-on, or harvested within short time-frames? Is it even possible to deal with such contingencies? Other scenarios might relate to the occurrence of Harmful Algal Blooms in close proximity, or upwelling events which rapidly increase algal productivity.

7.5 Recommendations to research organisations

The research priorities for oyster growers are set out in Section 5.3 and should be used in considering research that is applied to oyster aquaculture.

7.5.1 Include growers, industry and policy-makers in framing research questions

Researchers should continue to develop and implement participatory approaches for identifying priorities and framing research questions. This will enable better targeted research programs and outputs which have greater salience, credibility and legitimacy for their users (see Cash et al., 2003).

7.5.2 Recognise the capacity of growers to contribute to research through collection and analysis of data

The development of distributed research networks for applied research activity can be developed to include oyster growers in citizen science program may become increasingly the norm for reducing research costs and ensuring research outputs have legitimacy for end-users. Contemporary thinking about development of adaptive capacity stresses the need for knowledge-action systems in which the production of knowledge is distributed so that end-users have ownership of information and are involved in social learning and deliberative decision-making (Kates et al., 2001; Cash et al., 2003; Armitage, 2007). In line with this sort of thinking, oyster growers participating in workshops often argued that it made sense for them to contribute to water quality monitoring programs. They have an interest in such data being collected. They are geographically well-placed to collect data. In some cases they already have strong partnerships with regional authorities and enthusiastic about developing a greater understanding of function and dysfunction in estuarine systems.

7.5.3 Ensure social and cultural outcomes are included as central elements of research

Increasing production is rarely the only goal for growers. Some of the most important challenges for oyster aquaculture highlighted in the assessing adaptive capacity relate to cultural inertia or social issues that prevent effective organisation and collaboration among growers. These issues could become the subject of action research, or more traditional social research. There is also potential that technical means of addressing problems can have substantial social and cultural implications, and these should always be considered in the context of such development.

7.6 State specific recommendations for collective actions

In this section, specific recommendations derived through the RCVA process are identified for each state. In line with the foregoing, many of these recommendations can be furthered through gradual processes, often through collaboration between governments, industry, growers and community.

7.6.1 New South Wales

- The targeted augmentation and integration of existing monitoring programs with physiological research is likely to enable analysis of environmental pre-cursors of oyster diseases. This will be important for ensuring ongoing survival and development of the SRO industry. This is particularly the case in estuaries and lakes where production is greatest and where human pressures on estuarine and freshwater systems are substantial and/or growing.
- It is recommended that a pilot monitoring program be investigated and initiated in the Southern Rivers CMA area in the south of the state. Vulnerability in this area is potentially greatest of all oyster growing areas under various climate change scenarios, yet the industry in this region has strong proactive leadership and good linkages with the Southern Rivers CMA.
- OISAS should include section of management for climate change risks and uncertainties, and how this management can be informed by existing monitoring and scientific programs.
- Regional NRM groups and need to be more thoroughly integrated into OISAS and resourced properly to undertake extension work for improved NRM in relation to OISAS obligations.
- Regional NRM bodies can be an efficient and locally-trusted means of improving communication networks between governments and growers and should be increasing supported by state government for their capacity to build linking social capital and undertake extension and social research within communities and across regions.
- Work needs to be done under OISAS and in collaboration with local governments to ensure planning for future land bases enables the ongoing development of the oyster industry. Inundation of current land bases is likely and movement of this vital infrastructure may become more urgent over the next 2-3 decades.

7.6.2 South Australia

PIRSA Aquaculture can improve industry relations and potentially improve practices and knowledge of staff through programs of field interaction in the sector, and potentially through collaborative projects, which may be oriented by MISA or SAARDI research initiatives or investigation of zoning developments.

- Models for adaptive co-management should be investigated by industry and PIRSA Aquaculture. The strength and coordination of industry in SA and well co-ordinated government interaction with industry through PIRSA Aquaculture could provide fertile ground for development of adaptive co-management arrangements. These would improve lines of communication between industry and government, and formalise accountability of cost-recovered aspects of government.
- Investigate augmentation of monitoring programs to establish baseline conditions and improved understanding of variability should be investigated in bays. To better understand the linkages between shelf processes, upwelling and biophysical conditions in bays, a scientific program for monitoring physical parameters of water in bays could be a useful development to serve both public and private interests. The complexity of processes in bays of South Australia is currently poorly understood and represents a substantial knowledge gap in relation to the environmental conditions that form the biophysical basis of the oyster industry. Research on the processes in bays needs to be integrated with research and monitoring of shelf processes undertaken through SAIMOS.

7.6.3 Tasmania

Like SA, oyster growers in TAS were generally optimistic about the balance of impacts of climate change, yet they highlighted a number of issues that could be addressed in order to develop adaptive capacity in sector. Some of these are detailed in the recommendations across jurisdictions.

- Investigate the integration of existing estuarine monitoring programs and datasets, and the potential to augment these programs to address regional knowledge gaps (Industry, Government, NRM bodies and TAFI)
- Continuous improvement and streamlining and of government process. A constraint to adaptation identified in the TAS workshop was the time taken for assessments of applications by state and local government agencies. Because of the low numbers of growers and lack of in-depth discussion it is not possible to pinpoint which processes are a priority for industry, though most of the processes discussed related to land-based planning and development, which was described as impeding flexibility to deal with emerging situations. Differing experiences discussed in the workshop indicate that some growers have a more favourable view of current process than others. Identification of priorities for improving process could be undertaken as an industry initiative. Clear information about the stages of planning and compliance processes and timelines for their completion should be made available by Local and State Government agencies (see Section 7.2.2).
- Investigate development of a Social Licence to Operate. Adaptive capacity in the Tasmanian oyster industry has potential to benefit from a policy approach similar to NSW OISAS. This policy framework could provide a clear social license to operate and ensure the oyster industry and others understand where oyster farming is a priority outcome. Such a policy could formalise a whole-of-government approach to the industry.
- Develop business models which enable growth of enterprises. Industry could help facilitate growth in the sector by researching and extending operational business models, by which managers are remunerated according to profit and/or productivity outcomes rather than through wages. There are likely to be many case studies that exemplify such models in Tasmania and elsewhere in Australia.

8 References

Land Use Planning and Approvals Act (1993) (Tasmania), http://www.austlii.edu.au/au/legis/tas/consol_act/lupaaa1993296/

Fisheries Management Act (1994) (New South Wales), http://www.austlii.edu.au/au/legis/nsw/consol_act/fma1994193/

ABARE (2006) *Australian Fisheries Statistics 2005*, ABARE, Canberra,

ABARE (2008) *Australian Fisheries Statistics 2007*, ABARE, Canberra,

ABARE (2009) *Australian Fisheries Statistics 2008* http://www.frdc.com.au/commercial/fishstats/Australian%20Fisheries%20Statistics%202008.pdf.,

Adger, W. N. (2003) 'Social capital, collective action and adaptation to climate change', *Economic Geography,* 79, 4, pp387-404

Allen, B. (2000) '1997-98 Papua New Guinea Drought: Perceptions of Disaster', in *El Nino: History and Crisis* (ed), The White Horse Press, Cambridge

Allen Consulting (2005) *Climate Change Risk and Vulnerability*, Australian Greenhouse Office, Department of Environment and Heritage, Canberra, Australia,

Armitage, D. (2007) 'Building resilient livelihoods through adaptive co-management: the role of adaptive capacity', in *Adaptive Co-management: collaboration, learning and multi-level governance*, D. Armitage, Berkes , F. and Doubleday, N. (ed), UBC Press 2007, Vancouver, Canada

Armitage, D., Berkes , F. and Doubleday, N. A., D., Eds. (2007) *Adaptive Co-management: collaboration, learning and multi-level governance*, UBC Press 2007, Vancouver, Canada

Barnett, J. and Adger, W. N. (2003) 'Climate dangers and atoll countries', *Climatic Change* 61 pp321-337

Berkes, F. and Folke, C., Eds. (1998) *Linking Social and Ecological Systems: management practices and social mechanisms for building resilience*, Cambridge University Press, London

Bray, D. and von Storch, H. (1999) 'Climate Science: an empirical example of post-normal science', *Bulletin of the American Meteorological Society,* 80, 3, pp439-455

Brown, P. R., Nelson, R., Jacobs, B., Kokic, P., Tracey, J., Ahmed, M. and DeVoil, P. (2010) 'Enabling natural resource managers to self-assess their adaptive capacity', *Agricultural Systems,* ppdoi:10.1016/j.agsy.2010.06.004.

Butt, D., Shaddick, K. and Raftos, D. (2006) 'The effect of low salinity on phenoloxidase activity in the Sydney rock oyster, Saccostrea glomerata', *Aquaculture,* 251, 2-4, pp159-166

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jager, J. and Mitchell, R. B. (2003) 'Knowledge systems for sustainable development', *Proceedings of the National Academy of Sciences of the United States of America,* 100, 14, pp8086-8091

Commonwealth of Australia (1992) 'National Strategy of Ecologically Sustainable Development', http://www.environment.gov.au/esd/national/nsesd/strategy/intro.html, accessed 15th June, 2010

Dean, M. (1999) *Governmentality: Power and Rule in Modern Society*, Sage, London

Douglas, M. (1985) *Risk Acceptability According to the Social Sciences*, Russel Sage Foundation, New York

Douglas, M. (1992) *Risk and Blame*, Routledge, London

Ellis, F. (2000) *Rural Livelihoods and Diversity in Developing Countries*, Oxford University Press, Oxford, England

Forrest, B. M., Keeley, N. B., Kopkins, G. A., Webb, S. C. and Clement, D. M. (2009) 'Bivalve aquaculture in estuaries: Review and synthesis of oyster cultivation effects', *Aquaculture* 298, pp1-15

Frickel, S. and Vincent, M. B. (2007) 'Hurricane Katrina, contamination, and the unintended organization of ignorance', *Technology in Society,* 29, 2, pp181-188

Funtowicz, S. O. and Ravetz, J. R. (1993) 'Science for a post-normal age', *Futures,* 25, 7, pp739-55

Gazeau, F., C., Q., J.M., J., J-P., G., J.J., M. and C.H.R., H. (2007) 'Impact of elevated CO2 on shellfish calcification', *Geophysical Research Letters,* 34,

Grose, M. R., Barnes-Keoghan, I., Corney, S., Bennett, J., White, C. J., Holz, G. K., Gaynor, S. and Bindoff, N. L. (In Press) *Climate Futures for Tasmania: Methods and results on general climate*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Australia

Gunderson, L. H. and Holling, C. S., Eds. (2001) *Panarchy: understanding transformation in human and natural systems*, Island Press, Washington

Gunderson, L. H., Holling, C. S. and Light, S. S., Eds. (1995) *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, Columbia University Press, New York

Guston, D. H. (2001) 'Boundary organisations in environmental policy and science: an introduction', *Science, Technology and Human Values,* 26, 1, pp399-408

Hallegatte, S. (2009) 'Strategies to adapt to an uncertain climate change', *Global Environmental Change,* 19, 2, pp240-247

Hallegraeff, G. M. (1992) 'Harmful algal blooms in the Australian region', *Marine Pollution Bulletin,* 25, 5-8, pp186-190

Hallegraeff, G. M. (2010) 'Ocean climate change, phytoplankton community responses and harmful algal blooms: a formiddable predictive challenge', *Journal of Phycology,* 46, 2, pp220-35

Harvell, C. D., Kim, K., Burkholder, J. M., Colwell, R. R., Epstein, P. R., Grimes, D. J., Hofmann, E. E. and Lipp EK, O. A., Overstreet RM, Porter JW, Smith GW, Vasta GR. (1999) 'Emerging marine diseases - climate links and anthropogenic factors', *Science* 285, pp1505-1510

Hennessy, K., Fitzharris, B., Bates, B. C., Harvey, N., Howden, S. M., Hughes, L., Salinger, J. and Warrick, R. (2007) 'Australia and New Zealand', in *Climate Change 2007: Impacts, Adaptation and Vulnerability.Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M. L. Parry, Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and Hanson, C. E. (ed), Cambridge University Press, Cambridge, UK

His, E., Robert, R. and Dinet, A. (1989) 'Combined effects of temperature and salinity on fed and starved larvae of Mediterranean mussel *Mytilus galloprovincialis* and the Japanese oyster *Crassostrea gigas*', *Marine Biology* 100, pp455-463

Hobday, A. J., Okey, T. A., Poloczanska, E. S., Kunz, T. J. and Richardson, A. J., Eds. (2006) *Impacts of climate change on Australian marine life: Part A. Executive Summary.*, Report to the Australian Greenhouse Office Canberra, Australia.

Hobday, A. J., Poloczanka, E. S. and Matear, R. J., Eds. (2008) *Implications of Climate Change for Australian Fisheries and Aquaculture: a preliminary assessment*, Report to the Department of Climate Change, Canberra, Australia

Holling, C. S. (1973) 'Resilience and stability of ecological systems', *Annual Review of Ecology and Systematics,* 4 1-23

Innes, J. E. and Booher, D. E. (2003) 'Collaborative policy-making: governance through dialogue', in *Deliberative Policy Analysis: understanding governance in the network society*, M. Hajer and Wagenaar, H. (ed), Cambridge University Press, Cambridge, UK

IPCC (2007) *Climate Change 2007: Synthesis Report. An assessment of the Intergovernmental Panel on Climate Change*, IPCC,

Ison, R. (2002) 'Systems practice and the design of learning systems: orchestrating an ecological conversation', An interdisciplinary dialogue: agriculture and ecosystems management, Ballina, Australia

Kämpf, J., Doubell, M., Griffin, D., Matthews, R. L. and Ward, T. M. (2004) 'Evidence of large seasonal coastal upwelling system along the southern shelf of Australia', *Geophysical Research Letters* 31, pp1-12

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., McCarthy, J. J., Schellnhuber, H. J., Bolin, B., Dickson, N. M., Faucheux, S., Gallopin, G. C., Grubler, A., Huntley, B., Jager, J., Jodha, N. S., Kasperson, R. E., Mabogunje, A., Matson, P. and Mooney, H. (2001) 'Sustainability Science.' *Science,* 292, 5517, pp641

Kwa, C. (2001) 'The rise and fall of weather modification: changes in American attitudes toward technology, nature and society', in *Changing the Atmosphere: expert knowledge and environmental governance*, C. A. Miller and Edwards, P. N. (ed), MIT Press, Cambridge, MA

Li, X. (2008) *Reduction in Pacific oyster mortality by improving farming and processing technologies in South Australia*, South Australian Research & Development Institute, Adelaide, South Australia, pp.147

Li, X. and Clarke, S. (2010) *SEAP climate change assessment on Pacific oysters.*, South East Australia Program,

Li, Y., Qin, J., Abbott, C., Li, X. and Benkendorff, K. (2007) 'Synergistic impacts of heat shock and spawning on the physiology and immune health of Crassostrea gigas: An explanation for summer mortality in Pacific oysters', *American Journal of Physiology: Regulatory, Integrative and Comparative Physiology* 293, 2353-2362

Lockwood, M., Davidson, J., Curtis, A., Stratford, E. and Griffith, R. (2009) 'Multi-level governance: lessons from Australian natural resource management', *Australian Geographer,* 40, 2, pp169-89

Middleton, J. F. and Bye, J. A. T. (2007) 'A review of the shelf-slope circulation along Australia's southern shelves: Cape Leeuwin to Portland', *Progress In Oceanography,* 75, pp1-41

Mount, R. J. (2008) *Estuarine, Coastal and Marine National Condition Assessment*, <http://www.nlwra.gov.au/products/pn21454>, National Land and Water Resources Audit, Hobart, Tasmania,

Nell, J. A. (2001) 'The history of oyster farming in Australia', *Marine Fisheries Review,* 63, 3, pp14-25

Nell, J. A. (2007) *Diseases of Sydney Rock Oysters*, Prime Facts, 589, New South Wales Department of Primary Industry, http://aquanic.org/species/shellfish/documents/Diseases-of-Sydney-rock-oysters.pdf

Nell, J. A. and Holliday, J. E. (1988) 'Effects of salinity on the growth and survival of Sydney rock oyster (*Saccostrea commercialis*) and Pacific oyster (*Crassostrea gigas*) larvae and spat ', *Aquaculture,* 68, 1, pp39-44

Nelson, D., Adger, W. and Brown, K. (2007) 'Adaptation to environmental change: contribution of a resilience framework', *Annual Review of Environment and Resources,* 32, pp395-419

Nelson, R., Kokic, P., Crimp, S., Meinke, H. and Howden, M. (2009) 'The vulnerability of Australian agriculture to climate variability & change: Part I -Conceptualising and measuring vulnerability', *Environmental Science & Policy,* In press,

New South Wales Department of Natural Resources (2010) 'Estuaries in New South Wales', http://www.dnr.nsw.gov.au/estuaries/index.shtml, accessed 8th July, 2010

New South Wales Department of Primary Industry (2006) *The NSW Oyster Industry Sustainable Aquaculture Strategy*, New South Wales Government, Sydney, Australia,

NSW Department of Primary Industries (2006) *New South Wales Oyster Industry Sustainable Aquauculture Strategy*. Sydney N. DPI,

Ostrom, E. (1990) *Governing the Commons: the evolution of institutions for collective actions*, Cambridge University Press, New York

Ostrom, E. (2007) 'A diagnostic approach for going beyond panaceas', *Proceedings of the National Academy of Sciences of the United States of America,* 104, 391, pp15181-7

Ostrom, E. (2009) 'A general framework for analyzing sustainability of social-ecological systems', *Science,* 325, pp419-422

Oulton, L. J. (2009) *Assessing the impact of anthropogenic climate change on the aquaculture industry in South Australia: abalone as a case example*, University of London.

Oyster Tasmania (2010) 'Oysters Tasmania', http://www.oysterstasmania.org/, accessed 10 June, 2010

Pahl-Wostl, C. (2009) 'A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes', *Global Environmental Change,* 19, 3, pp354-365

Parker, L. M., Ross, P. M. and O'Connor, W. A. (2009) 'The effect of ocean acidification and temperature on the fertilization and embryonic development of the Sydney rock oyster *Saccostrea glomerata* (Gould 1850)', *Global Change Biology,* 15, 9, pp2123-2136

Parker, L. M., Ross, P. M. and O'Connor, W. A. (In press) 'Comparing the effect of ocean acidification and temperature on the reproduction and early development of two species of oysters', *Marine Biology,*

Primary Industries Ministerial Council (2005) *Best Practice Framework for Regulatory Arrangement for Aquaculture in Australia* Department of Agriculture Forestry and Fisheries, Canberra,

Quayle, D. B. (1969) 'Pacific oyster culture in British Columbia', *Bulletin of Fisheries Research Board of Canada*, pp192

Rubio, A. (2008) *Environmental Influences on the sustainable production of the Sydney rock oyster Saccostrea glomerata: A study in two southeastern Australian Estuaries*. Canberra, Australian National university.

Ruesnik, J. L., Lenihan, H. S., Trimble, A. C., Heiman, K. W., Micheli, F., Byer, J. E. and Kay, M. C. (2005) 'Introduction of non-native oysters: ecosystem effects and restoration implications', *Annual Review of Ecology and Systematics,* 36, pp643-689

Scoones, I. (1998) *Sustainable Rural Livelihoods: a framework for analysis*, Institute of Development Studies, Shackley, S. and Wynne, B. (1996) 'Representing uncertainty in global climate science and policy: boundary ordering devices and authority', *Science, Technology and Human Values,* 21, 3, pp275-302

Shpigel, M. and Blaylock, R. A. (1991) 'The Pacific oyster, *Crassostrea gigas*, as a biological filter for a marine fish aquaculture pond', *Aquaculture* 92, pp187-97

Smith, I. R., Nell, J. A. and Adlard, R. (2000) 'The effect of growing level and growing method on winter mortality, Mikrocytos roughleyi, in diploid and triploid Sydney rock oysters, Saccostrea glomerata', *Aquaculture,* 185, 3-4, pp197-205

Star, S. L. and Griesemer, J. R. (1989) 'Institutional ecology, "translation," and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology', *Social Studies of Science,* 19, 3, pp387-420

Taris, N., Lang, R. P., Reno, P. W. and Camara, M. D. (2009) 'Transcriptome response of the Pacific oyster (*Crassostrea gigas*) to infection with *Vibrio tubiashii* using cDNA AFLP differential display', *Animal Genetics* 40, pp663-677

Thompson, P. A., Baird, M. E., Ingleton, T. and Doblin, M. A. (2009) 'Long-term changes in temperate Australian coastal waters: implications for phytoplankton', *Marine Ecology Progress Series,* 394, pp1-19

Thomson, D. and Pepperdine, S. (2004) *Assessing Community Capacity for Riparian Restoration*, Land & Water Australia, Canberra, pp.55

Turner, B. L., Kasperson, R. E., Matsone, P. A., McCarthy, J. J., Corellg, R. W., Christensene, L., Eckley, N., Kasperson, J. X., Luerse, A., Martellog, M. L., Polskya, C., Pulsiphera, A. and Schillerb, A. (2003) 'A framework for vulnerability analysis in sustainability science', *Proceedings of the National Academy of Sciences of the United States of America,* 100, 14, pp8074-9

White, I. (2001) *Safeguarding Environmental Conditions for Oyster Cultivation in New South Wales*, http://www.hrc.nsw.gov.au/site/pdf/reports/oysters_final.pdf., Centre for Resource and Environmental Studies, Australian National University,

Wolf, P. H. and Collins, A. J. (1977) *Summary of daily temperature and salinity records for major oyster-bearing estuaries of New South Wales 1966-1973*, NSW State Fisheries, Sydney, NSW pp.107

Zimmerman, A. M., De Paola, A., Bowers, J. C., Krantz, J. A., Nordstrom, J. L., Johnson, C. N. and Grimes, D. J. (2007) 'Variability of total and pathogenic Vibrio parahaemolyticus densities in northern Gulf of Mexico water and oysters', *Applied Environmental Microbiology,* 73, pp7589-7596

9 Appendix 1: Possible project actions and future research suggested in policy workshops

9.1.1 New South Wales

1. Develop a component of the grower workshops in which growers can talk about changes in the system and observed impacts / changes associated with climate in their locality.
2. Discuss major transformation of businesses and uptake of EMSs etc within the Hawkesbury River with Rob Moxom and Ana Rubio.
3. Discuss changing distribution of Phytoplankton blooms and potential Harmful Algal Blooms with Gustaf Hallegraaf
4. It would be useful to have a better understanding of how growers are currently considering climate change and adaptation and this may require investment in survey research to supplement the findings of this project.
5. Use workshops to emphasise possibilities associated with CC: these including funding for works and equipment, using CC as lever to encourage action such as Councils to manage point source contamination, regional NRM bodies to ensure riparian management.
6. Stress no-regrets options for CC adaptation in workshops.
7. Workshops with growers will need to be at high tide and for no more than half the day. Recommended workshop locations were Wallis Lake (including invites to Hastings River growers??) and the Hawkesbury River (including invitations to Georges River growers) and Clyde River if three workshops are possible
8. Follow up with Wayne O'Connor on how changes in environmental flows can impact of changes in disease prevalence following work done in Florida. Provide environmental flows and Wayne will provide illustration of what oyster impacts might be.

9.1.2 South Australia

A proportion of industry members are likely to be interested in a workshop that: 1) communicates some of the latest research on climate change and local drivers of system function, and; 2) emphasises that the workshop outputs will inform a broader policy process, and thus they provide an opportunity for growers to frame policy and research questions. As the process is not run by government or research organisations, no promises can be made about the policy and research outcomes of the process, other than these government agencies have said they will review these outputs with interest and in good faith.

1. Discuss currents, upwelling and possibilities for changes and unusual events in these with John Middleton and compile component of presentation for growers.
2. Follow up with researchers from Flinders University on temperature thresholds for oyster mortality (Summer Mortality) related to extreme air / water temperature, and incorporate into grower presentation.
3. Follow-up on wine industry adaptation work in SA
4. Follow-up with Stephen Madigan on the function of extension for the oyster industry.
5. Design SA grower workshops to include scenario mapping exercise that relates to plausible event(s) which might shed light on policy and practice options for dealing with changing.
6. Design SA grower workshops to include an account of things that researchers are concerned about in order for growers to reflect on these things and prioritise these areas of research.
7. Design SA grower workshops to include discussion of how growers are currently dealing with extreme conditions such as storms and heatwaves, and the ways infrastructure and planning may be changing. Include aspect of this question to highlight where and how current policy instruments constrain adaptation or flexible management.

9.1.3 Tasmania

A proportion of industry members are likely to be interested in a workshop that: 1) communicates some of the latest research on climate change and local drivers of system function, and; 2) emphasises that the workshop outputs will inform a broader policy process, and thus provide an opportunity for growers to frame policy and research questions which are relevant to them. As the process is not run by government or research organisations, no promises can be made about the policy and research outcomes of the process, other than these government agencies have said they will review these outputs with interest and in good faith.

Actions and considerations stemming from this discussion are as follows:

1. TSQAP data (from Ray Brown) to examine changes in flooding and estuary closures if possible, and changes in the water quality over the years.
2. Need to be very careful about the management of meetings with growers and define what can and cannot be included in discussion. It is possible that some growers will express doubts about whether climate change is a real concern and this will need to be pre-empted in the design of the workshop.
3. Focus of workshop in terms of hazards and timescales, and potential to adapt to particular impacts. In this context a central focus for industry and growers is likely to be on events that can occur at short timescales (such as flooding, droughts, toxic algal blooms, storm surges) as these are the events likely to be of greatest interest to oyster growers, and the ones most able to be managed at a local and industry level. Gradual changes are likely to be more important in informing policy, lease arrangements and zoning over the longer term. These hazards need to be described in terms of what is expected and likely to happen both as biophysical impacts and how they might impact on survivorship of oysters and changes in production, if this is possible.
4. Workshop could be run with breakout sessions in which people from different spheres (industry, growers and hatchery industry people and policy/management) can interact.
5. Christine Crawford will follow up with Geoff Ross about environmental flows modelling and the impacts on estuary.
6. The project management for the Tasmanian food bowl project needs to be consultative Environmental flows project
7. Questions arising to do with adaptive capacity include: issues about demographics: what is the age structure among farmers? Have there been significant changes in collaboration or innovation? How variable are the approaches to farming (large-scale innovative operators and lifestyle operators)?
8. The Climate Change Office may be a key port of call to discuss whole of a government approach to management of estuary health in relation to climate change and long-term strategic planning.
9. The workshop needs to stress the need for collective action across industry and government. It presents an opportunity for better integration across government agencies as well as better organisation within industry. This is particularly the case in the context of the timing of workshops and outputs in relation to election of an incoming government.
10. It will be useful to develop a Ministerial briefing with the Climate Change Office identifying the key issues and policy implications that have been identified in this process.

10 Appendix 2: Example regional workshop agenda

Workshop: Climate adaptation in the oyster industry

PORT LINCOLN, Marine Science Centre, 11.30am-5.00pm

11:30 – 11:50 Welcome: Introduction to the workshop and project

An outline of ARN-MBR and the project as policy-oriented research, climate change impacts adaptation and vulnerability. Outline of the workshop, and its focus on climate change impacts and adaptive capacity.

11:50 -12:20 Biophysical changes observed in regions and how people have responded to them

Discussion of key observed changes and what is being done to adapt to these changes by growers, industry and government (20 minutes)

Level of concern about these changes** In relation to their impact on oyster aquaculture, how would you rate your level of concern about each change? (List of changes with ordinal responses) (10 minutes)

12:20 -1:10 Presentation of the latest science (CC impacts and adaptation) and questions

- Based on timescale of impacts: from weather events to inter-annual to inter-decadal to long term trends
- Highlight changes in key system drivers (SA – upwelling and currents, heatwaves and disease; NSW and TAS: flood frequencies, drought and other features affecting environmental flows and disease that relate to CC)

1:10 – 1:2:15 Lunch and presentation from Trudy McGowan about SAOGA/SAORC activities

(SA have longer lunch with Trudy talking at the end of lunch)

2:15 – 2:30 Prioritisation of climate change and adaptation research (as discussed in presentation)

What research is most important and useful for allowing growers to make decisions about adaptation?

2:30 – 3:10 Scenario mapping

- Break workshop group into two groups to discuss two different scenarios of events and how these would be dealt with (in SA: upwelling of anoxic water? Increased storm frequency?; in NSW and TAS: high frequency flooding and continuous estuary closures, PSP algal blooms)
- Identify key issues and constraints for action that would need to be taken to manage these risks

3:10 – 4:00 Rapid appraisal of Adaptive Capacity (longer term drivers of adaptation)

What constrains and enables adaptation in the region? Identification of indicators of Social, Human, Financial, Physical and Natural Capitals, the reason why each is important and actions needed to build capacity in relation to these indicators.

4:00 -4:10 Tea break 10 minutes

During tea break, W/S facilitators to prepare indicators for rating using turning point**

4:10 – 4:40 Rating adaptive capacity indicators**

Rating the indicators developed in previous session, to gauge their relative importance for building adaptive capacity in sector and region.

4:40 – 4:45 Workshop evaluation**

Informal discussion of sources of funds, information and collaboration to work towards adaptation

Workshop ends

** indicates the use of turning point (keepad technology) to get feedback

11 Appendix 3: Outline of governance arrangements across NSW, SA and TAS

	New South Wales	South Australia	Tasmania
Legislation	Fisheries Management Act 1994	*Aquaculture Act* 2001 *Aquaculture Regulations* 2005 and the *Livestock Act* 1997,	*Marine Farming Planning Act* 1995, *Living Marine Resources Management Act* 1995
Primary Agency	Industry and Investment NSW	PIRSA Aquaculture Division	Marine Farming Branch (MFB) of DPIPWE
Advisory Bodies	Peak Oyster Advisory Group (POAG), Shellfish Quality Assurance Committee (SQAC), Aquaculture Research Advisory Committee (ARAC).	Aquaculture Advisory Committee - advice to the minister Aquaculture Tenure Allocation Board (ATAB) – allocation of tenure PIRSA Biosecurity Division – Biosecurity matters	Marine Farming Planning Review Panel, Tasmanian Oyster Research Council (TORC).
Key Policy Documents	Oyster Industry Sustainable Aquaculture Strategy (OISAS)	PIRSA Aquaculture – Ecologically Sustainable Development Risk Assessment Guidelines PIRSA Aquaculture zone policies	Marine Farming Development Plans *State Coastal Policy* 1996 *State Policy on Water Quality Management* 1997.
Management Framework	Zones –Priority Oyster Aquaculture Areas (POAAs) Lease Aquaculture Permit	Zones (exclusion, aquaculture, prospective, harvest) Leases (pilot, development, production) Licenses Emergency Leases Emergency Zones	Marine Farm Development Plan specifies zones for oyster aquaculture Lease License
Lease tenure	Standard 15 year	Renewal terms as stipulated in *Aquaculture Act 2001* – terms are based on development rates. Pilot Lease – max 1 year term (3 years total) Development Lease – max 3 year term (9 years total) Production Lease – max 20 year term	30 year
Licenses	Aquaculture permit - perpetual	Landbased licence max 10 year term	Annual
Movement of Oysters	Restrictions on Pacific Oyster and QX disease specified under OISAS and	Any stock moving between licences known to be affected with disease must obtain	No restrictions at present

	regularly updated	written consent from the minister to do so (Section 12, *Aquaculture Regulations 2005*) Organisms received, organisms bred on site and the organisms supplied to another person must be recorded on the stock register for each licence (Regulation 13*, Aquaculture Regulations 2005*)	
Closures	Rules in place (governed by NSW Shellfish Program NSW Food Safety)	Rules in place (Governed by SASQAP)	Rules in place (Governed by TAS Shellfish Quality Assurance Program TSQAP)
Industry	NSW Farmer's Association Oyster Committee Aquaculture Research Advisory Committee (ARAC) Peak Oyster Advisory Group (POAG)	South Australian Oyster Growers Association (SAOGA) South Australian Oyster Research Council Pty Ltd (SAORC)	Oysters Tasmania Tasmania Oyster Research Council (TORC)
Environmental monitoring and management	NSW Monitoring, Evaluation and Reporting and Investment (MERI) provides a framework for monitoring of estuaries, which are managed under estuary specific catchment management plans, co-ordinated by local councils with the assistance of CMAs and the Department of Natural Resources.	Annual environmental monitoring reports to be submitted as per the (Regulation 23, *Aquaculture Regulations 2005*). EMP programs can be changed on an annual basis to address current risks. Unusual mortality reports must be reported to PIRSA Aquaculture as soon as practicable (Regulation 11, *Aquaculture Regulations 2005*). SASQAP water quality monitoring.	Specific monitoring is required under MFPDs, which are developed on the basis of initial Environmental Impact Assessment of zones. Monitoring of estuarine water quality is achieved through targeted local, regional and other programs and projects, and DPIPWE co-ordinates the Statewide Baseline Water Quality Monitoring Program and the Pesticide Monitoring in Water Catchments.
Quality assurance/ food safety	NSW Shellfish Program NSW Food Safety	South Australian Shellfish Quality Assurance Program (SASQAP)	Tasmanian Shellfish Quality Assurance Program (TASQAP)
Adaptive Responses	Aquaculture permits can be amended at short notice	Emergency lease and zone provisions License conditions can be amended Lease conditions can be	Emergency lease and zone provisions License condition can be amended

amended
Applications can be submitted for movements, subdivision, surrender of leases and variation, movement, subdivision of licences.

12 Appendix 4: Data on which classification of indicators was based

NB: In each of the tables the indicator is rated on the two continuums (constraining – enabling, and stable-unstable) on a 6-point scale (1-7) where 1 is the lowest possible score and 7 the highest. For each of the indicators the mean value on each continuum is presented for 'all participants' and 'oyster growers' in order to examine the variance between and within group. The standard deviation is also given as a measure of the variance around each mean. All these values are descriptive and should not be considered in terms of statistical significance.

BATEMANS BAY

Captial	Indicator	CONSTRAINING - ENABLING				UNSTABLE - STABLE			
		All participants (n=17)		Oyster Growers (n=10)		All participants (n=17)		Oyster Growers (n=10)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Human Capital	Individualism in industry	2.3	0.8	2.4	0.8	4.1	1.9	3.8	2.1
	Conservatism	2.5	1.0	2.7	1.3	4.3	1.8	4.0	2.2
	Support for leadership	3.6	1.7	3.8	1.6	3.4	1.5	3.2	1.9
	Time constraints	2.0	0.8	1.7	0.8	4.7	1.8	4.4	2.1
	Lack of skilled labour	2.5	1.1	2.4	1.3	4.2	1.8	3.5	2.0
Social Capital	Communication with industry	2.4	1.6	2.5	1.6	3.6	1.8	3.3	1.9
	Government engagement strategies	3.4	1.8	3.4	2.1	2.9	1.4	2.9	1.4
	Data collection and collation	2.2	1.0	2.2	1.1	2.8	1.8	2.5	1.7
	Farmers' ability to engage in decision-making	3.0	1.7	2.6	1.7	2.8	1.6	2.4	1.8
	Industry engagement with broader community	3.3	1.3	3.8	1.4	3.8	1.6	4.0	1.5
Natural Capital	Access to water	1.9	1.1	2.1	1.3	2.9	1.4	2.8	1.5
	Water quality	2.4	1.5	3.1	1.4	3.3	2.1	3.5	2.3
	Inundation of land bases	2.9	1.1	2.8	1.2	3.4	2.3	2.7	2.2
	Seed stock resilience	3.3	1.7	3.6	2.2	3.8	1.7	3.7	1.8
Physical Capital	Identification of suitable landbases	2.8	1.2	2.8	1.4	3.1	1.4	3.0	1.5
	Availability of seed stock	2.5	1.3	2.7	1.4	2.8	1.5	2.4	1.3
Financial Capital	Lack of profitability	1.9	1.7	1.9	1.9	3.0	2.2	3.1	2.4
	Valuation of leases as capital	2.1	0.9	1.8	0.8	4.5	2.2	4.0	2.4
	Supply chain issues	2.4	1.2	2.2	1.1	4.0	1.8	3.5	1.9

FORSTER

Captial	Indicator	CONSTRAINING - ENABLING				UNSTABLE - STABLE			
		All participants (n=9)		Oyster Growers (n=8)		All participants (n=9)		Oyster Growers (n=8)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Human Capital	Education and training	3.9	1.6	3.9	1.6	2.9	1.7	2.6	1.6
	Apathy	2.3	1.0	2.4	1.1	3.6	1.5	3.8	1.5
	Time constraints	2.1	0.3	2.1	0.4	3.4	1.6	3.3	1.6
	Age / time in industry	3.7	1.0	3.6	1.1	3.5	1.7	3.1	1.5
Social Capital	Perception of oyster industry/aquaculutre	3.2	1.5	3.4	1.5	2.3	0.5	2.3	0.5
	Coordination of governance	2.8	1.7	3.0	1.7	4.2	1.7	4.1	1.8
	Interaction between growers	5.2	1.8	5.5	1.7	4.2	1.6	4.4	1.7
	Industry-government relations	4.7	1.8	5.0	1.6	4.1	1.2	4.4	0.9
Natural Capital	Estuary health	2.8	1.7	3.0	1.7	4.2	1.7	4.1	1.8
	Water purity	3.2	1.1	3.4	1.1	4.0	1.2	3.9	1.2
	Frequency of heatwaves	3.3	0.7	3.4	0.7	5.1	2.2	4.9	2.2
	Primary productivity in estuary	3.5	1.6	3.6	1.7	4.2	1.9	4.3	2.0
Physical Capital	Adoption of new infrastructure	5.0	1.4	5.1	1.5	3.3	1.3	3.4	1.4
	Choice of product	5.1	0.9	5.0	0.9	3.2	1.5	3.3	1.6
	Relocation of product	4.0	1.3	4.0	1.4	3.7	0.7	3.6	0.7
Financial Capital	Financial overheads	3.0	1.3	3.1	1.4	4.2	1.4	4.1	1.5
	Profitability	3.8	1.3	3.9	1.4	2.9	0.8	3.0	0.8
	Protection of industry investment	3.9	1.7	4.1	1.6	4.2	1.1	4.1	1.1

CAMPBELL TOWN

		CONSTRAINING - ENABLING				UNSTABLE - STABLE			
		All participants (n=11)		Oyster Growers (n=6)		All participants (n=11)		Oyster Growers (n=6)	
Captial	**Indicator**	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Human Capital	Enterprise structure	3.2	1.1	3.0	1.0	2.9	1.1	2.7	1.2
	Knowledge of owner operators	5.3	1.4	5.4	0.5	2.7	1.9	2.3	1.7
	Availability of training	4.8	1.7	5.8	1.6	3.3	1.8	2.8	2.0
	Industry attraction to staff	1.9	0.7	2.0	0.7	3.8	1.5	3.5	1.6
Social Capital	Efficiency of process	2.5	1.4	2.2	0.9	5.6	1.8	5.2	2.0
	Flow of information	4.9	1.5	4.7	1.7	2.4	0.9	2.0	0.8
	Relationships with state government agencies	3.3	1.6	2.7	1.3	3.9	1.6	4.4	1.8
	Industry representation	4.6	1.9	4.5	2.2	2.6	1.0	2.8	1.1
	Whole of catchment management	2.7	1.3	3.5	1.3	4.4	1.3	4.8	1.1
Natural Capital	Environmental flows	3.1	1.2	3.5	1.0	5.0	1.7	5.7	1.7
	Access to foreshore	3.5	1.2	3.5	1.5	5.3	1.6	5.8	1.1
	Size and position of farms	3.5	1.6	3.3	1.7	6.0	0.7	6.2	0.7
	Phytoplankton or Chlorophyll-a	4.2	1.4	3.5	1.3	3.8	2.0	3.3	1.9
Physical Capital	Spat availability	3.2	1.8	3.7	2.1	2.7	2.1	3.3	2.1
	Appropriateness of infrastructure	4.8	1.4	4.7	1.8	3.1	1.5	2.7	1.6
Financial Capital	Security of tenure	3.3	1.9	2.5	1.7	5.3	1.6	5.7	1.1
	Costs of fixed infrastructure	2.8	1.3	2.0	1.5	4.0	1.9	4.0	2.2
	Value of foreshore land	2.8	1.1	2.7	1.1	3.2	2.1	3.8	2.2
	Cost recovery arrangements	2.9	1.3	2.7	0.8	4.6	1.7	4.5	1.7
	Closure costs	2.7	0.8	2.8	0.7	3.4	1.7	4.2	1.6





UTAS

NCCARF
National
Climate Change Adaptation
Research Facility
Adaptation Research Network
MARINE BIODIVERSITY AND RESOURCES